STUDIES ON WESTERN AUSTRALIAN PERMIAN BRACHIOPODS 14. THE FAUNA OF THE ARTINSKIAN HIGH CLIFF SANDSTONE, PERTH BASIN

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The brachiopod fauna of the Early Permian High Cliff Sandstone, Perth Basin, Western Australia is reviewed and described. The following new taxa are documented: *Neochonetes (Sommeriella) magnus* sp. nov., *Taeniothaerus quadratiformis* sp. nov., *Neospirifer (Quadrospira) woolagensis* subgen. et sp. nov., *Occidalia shahi* gen. et sp. nov., *Woolagia playfordi* gen. et sp. nov., *Cleiothyridina perthensis* sp. nov. and *Hoskingia skwarkoi* sp. nov. The age of the fauna, important for the biostratigraphy of the Permian of the Perth Basin, is reviewed and an age of Late Aktastinian (Artinskian) is preferred for the High Cliff Sandstone.

BRACHIOPODS of Permian age have been known from the basal High Cliff Sandstone since the early 1950s. Initial reports, discussed below, indicated that the specimens were from the underlying Fossil Cliff Formation. Nevertheless the analysis of these early collections by Dickins (1957) and the detailed stratigraphical study by Playford (1959) demonstrated their true stratigraphical source. The present review of available collections indicates the distinctive faunal features of the basal High Cliff Sandstone assemblage and confirms the importance of the faunal zone based on the assemblage, outlined by Archbold (1993a) and named formally herein as the *Neochonetes (Sommeriella) magnus* Zone. The High Cliff Sandstone fauna is a distinctive Westralian (Archbold 1983a) assemblage but does include an endemic component in the fauna, restricted to the Perth Basin.

STRATIGRAPHY

References to the regional geology of the Permian sequences of the Perth Basin are provided in Archbold (1996: 17) and are not repeated here. The stratigraphy of the High Cliff Sandstone (Clarke et al. 1951) is described as the unit of interbedded sandstones, conglomerates and siltstones, apparently lying conformably, but usually with an abrupt contact, on the Fossil Cliff Formation (Fossil Cliff Member of some authors) and conformably overlain by the Irwin River Coal Measures (Playford et al. 1976; Le Blanc Smith & Mory 1995). Marine fossils are only known from the basal unit of the formation in the Woolaga Creek area (Playford 1959; see Fig. 1 herein) 27 km south of the type section which is at High Cliff on the north branch of the Irwin River (see P. E. Playford and S. P. Willmott in McWhae et al. 1958: 77). The type section of the High Cliff Sandstone is 26 m thick but at Woolaga Creek the unit is up to 42 m thick. Dickins (1963: 145) has provided significant evidence in support of a break in sedimentation, with possible subaerial erosion, at the base of the High Cliff Sandstone at Woolaga Creek.

According to Playford (1959: 18) approximately 1.5 m of generally pale yellowish-grey fine grained silty sandstone occurs at the base of the section at Woolaga Creek. Above this is some 10 m of red brown, ferruginous, fine to medium sandstone with marine fossils. All marine fossils are from the surface outcrops at Woolaga Creek and are preserved as ferruginous internal and external moulds.

PREVIOUS BRACHIOPOD STUDIES

The first formal descriptions and illustrations of brachiopod specimens from the High Cliff Sandstone were provided by Coleman (1957). However Coleman followed earlier opinions (Fairbridge 1952; Johnson et al. 1954) and considered that the material described (aulostegid and linoproductid productids) was from a facies variant of the Fossil Cliff Formation. Dickins (1957) was the first worker to recognise the distinctive nature of the fauna and his brachiopod determinations were repeated by Playford (1959: 19) and Playford et al. (1976: 98, 100). Campbell (1965) described a terebratuloid species, *Gilledia woolagensis*, and Runnegar (1969) illustrated an ingelarellid speci-

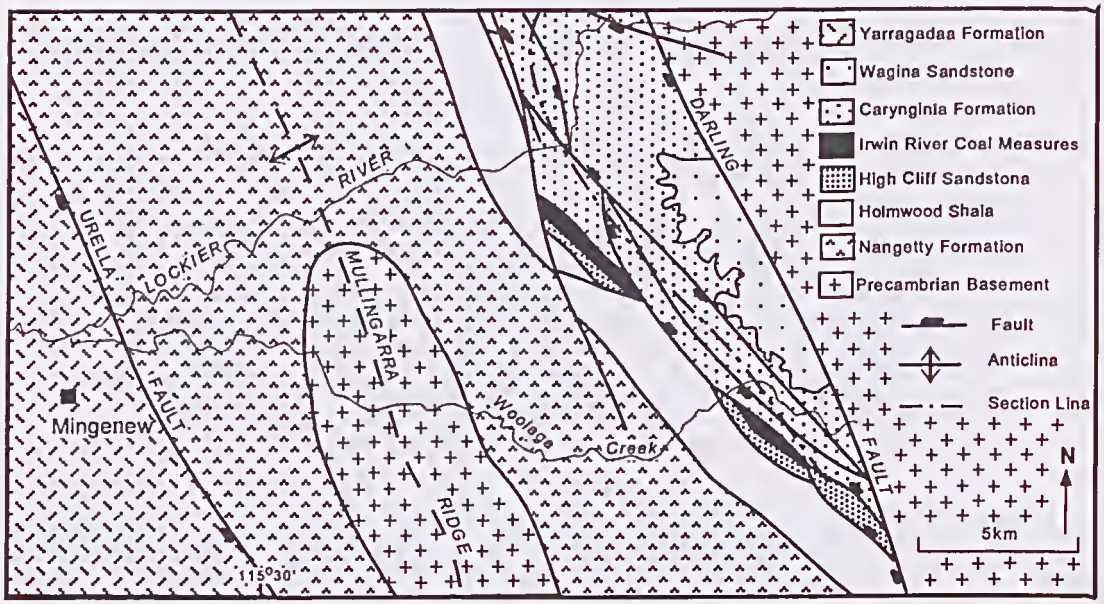


Fig. 1. Locality map of interpreted solid geology of the High Cliff Sandstone at Woolaga Creek (after Le Blanc Smith & Mory 1995: fig. 4).

men which was subsequently described as a new species, *Tomiopsis rarus*, by Archbold & Thomas (1986a). A revised list of the High Cliff Sandstone brachiopods was provided by Archbold (1988), used in part by Skwarko (1993) and several species were illustrated by Archbold et al. (1993) with brief diagnoses also being provided by those authors. A new species of the linoproductoid *Costatumulus* was described by Archbold (1993b). For the present study all previously described material was re-assessed.

COLLECTIONS

All specimens are registered with the Geological Survey of Western Australia (GSWA F), Perth; the Commonwealth Palaeontological Collections (CPC) of the Australian Geological Survey Organisation (AGSO), Canberra; the Western Australian Museum (WAM F), Perth or the University of Western Australia, Geology Department (UWA), Nedlands, Perth.

All illustrated specimens of new species, other than holotypes, are designated as paratypes.

AGE AND CORRELATION OF FAUNA

Dickins (1957) indicated that the fauna of the High Cliff Sandstone was intermediate in type between that of the Fossil Cliff Formation (and Callytharra Formation of the Carnarvon Basin) below and that of the Coyrie (Madeline) Formation of the Carnarvon Basin above. Archbold (1993a) proposed a zonation scheme based on brachiopods from the Permian of Western Australia. The *Neochonetes (Sommeriella)* sp. nov. A. Zone, now formally renamed the *Neochonetes (Sommeriella) magnus* Zone, was proposed for the fauna of the High Cliff Sandstone (also utilised in Archbold & Dickins 1996). However it was noted that the zone was not placed in an objective stratigraphical sequence (Archbold 1993a: 313) and that no direct correlatives of the zone were known elsewhere in Western Australian. The zone was placed provisionally, between the *Strophalosia jimbaensis* Zone, of the Jimba Jimba Calcarenite, above, and the *Strophalosia irwinensis* Zone of the Fossil Cliff Formation below.

The fauna of the Jimba Jimba Calcarenite of the Carnarvon Basin shares many species with the

fauna of the Fossil Cliff Formation of the Perth Basin and the Callytharra Formation of the Carnarvon Basin (Archbold & Shi 1993) and includes four distinctive species that are related to Callytharra Formation species (see Archbold & Shi 1993: 189, for a list of Jimba Jimba species). One Jimba Jimba species (*Tomiopsis* cf *T. rarus* Archbold & Thomas) is closely related to a High Cliff Sandstone species. It appears likely that the Jimba Jimba Calcarenite can be considered to be a top member of an extended and redefined Callytharra Formation (Mory 1996; see also Table 2 herein). This may explain the relative similarity of the Fossil Cliff–Callytharra fauna with that of the Jimba Jimba Calcarenite.

However it is apparent from the present study that the brachiopod fauna of the High Cliff Sandstone (Table 1) is quite distinct from that of

Streptorhynchus sp.
Neochonetes (Sommeriella) magnus sp. nov.
Chonetinella sp.
strophalosiid indet.
Aulosteges ingens Hosking 1931
Taeniothaerus quadratiformis sp. nov.
Costatumulus occidentalis Archbold 1993
Neospirifer (Quadrospira) woolagensis subgen. et sp. nov.
Occidalia shahi gen. et sp. nov.
Woolagia playfordi gen. et sp. nov.
?Cyrtella sp.
Tomiopsis rarus Archbold & Thomas 1986
Cleiothyridina perthensis sp. nov.
Composita sp.
Gilledia woolagensis Campbell 1965
Hoskingia skwarkoi sp. nov.

Table 1. Brachiopod fauna of the High Cliff Sandstone.

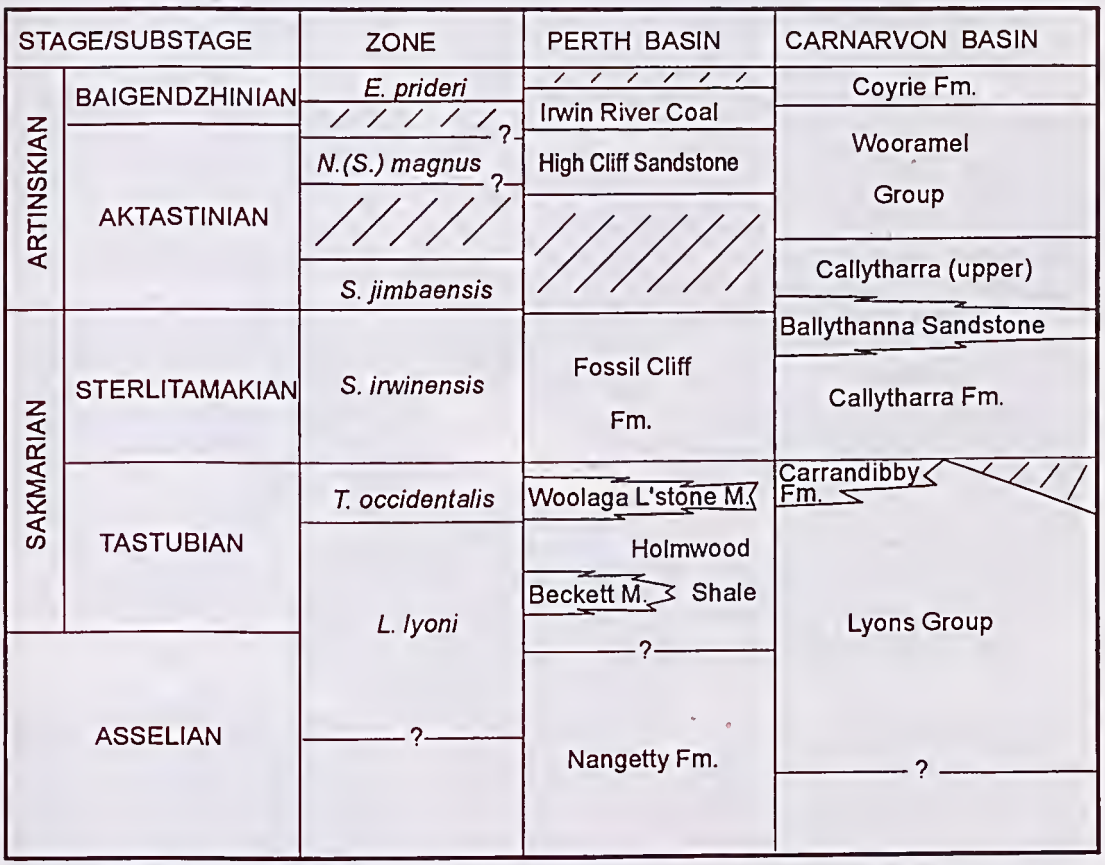


Table 2. Revised Early Permian brachiopod zones of Western Australia and correlation of Early Permian strata of the Perth and Carnarvon Basins. The usage of upper Callytharra Formation follows that of Mory (1996) and includes the Jimba Jimba Calcarenite of previous authors.

the Fossil Cliff Formation and is, in fact, rather more closely related to that of the Mingenew Formation and, in part, the fauna of the Coyrie and Madeline Formations of the Carnarvon Basin. No species are shared with the fauna of the Fossil Cliff Formation, whereas one is shared with the fauna of the Madeline Formation (*Aulosteges ingens* Hosking 1931), and the distinctive new genus *Occidalia* is shared with the fauna of the Mingenew Formation. Hence on the basis of these relationships, it appears that the *Neochonetes (Sommeriella) magnus* Zone, typified by the fauna of the High Cliff Sandstone, should probably be placed between the *Strophalosia jimbaensis* Zone below and the *Echinalosia prideri* Zone above (Table 2). If correct, this would imply that there is a relatively short time break between the deposition of the Fossil Cliff Formation and the High Cliff Sandstone at Woolaga Creek, perhaps indicated by both the abrupt nature of the contact and the abrupt change in facies between the two units (see also Dickins 1963: 145).

International correlations of the Western Australian Permian sequences have traditionally relied on the sporadic distribution of ammonoid species (see references in Archbold 1993a) described from spot localities within the Western Australian sequences. The present author follows Glenister et al. (1993) and considers that no Aktastinian ammonoids are known from Western Australia but that the Baigendzhinian (including the Kungurian in the usage of Glenister et al. 1993) is well represented. On this basis, and given the nature of the High Cliff Sandstone brachiopod fauna, it is considered that the *Neochonetes (Sommeriella) magnus* Zone is probably Aktastinian in age with a Sterlitamakian fauna known from the underlying Fossil Cliff Formation (Archbold 1995b).

SYSTEMATIC PALAEONTOLOGY

Phylum BRACHIOPODA

Order STROPHOMENIDA Opik, 1934

Suborder ORTHOTETIDINA Waagen, 1884

Superfamily ORTHOTETOIDEA Waagen, 1884

Family STREPTORHYNCHIDAE Stehli, 1954

Genus **Streptorhynchus** King, 1850

Type species. Terebratulites pelargonatus Schlotheim, 1816.

Streptorhynchus sp.

Fig. 3A–B

Comments. One incomplete internal mould of a dorsal valve (WAM 69.753) indicates the presence of a moderately sized *Streptorhynchus* within the High Cliff fauna (estimated width, 46 mm; valve height, 34 mm). The dorsal muscle field and cardinalia are typical of the genus. Costellae (2 per mm at anterior margin of valve) are sharp and usually increase by intercalation. The valve was relatively thin; traces of costellae extend posteriorly to the muscle field. Material is inadequate for detailed comparison with other Western Australian species but the specimen appears to belong to the finely costellated, thin shelled group of species that is well represented in the Westralian Permian Province.

Order CHONETIDA Nalivkin, 1979

Suborder CHONETIDINA Muir-Wood, 1955

Superfamily CHONETOIDEA Bronn, 1862

Family RUGOSOCHONETIDAE Muir-Wood, 1962

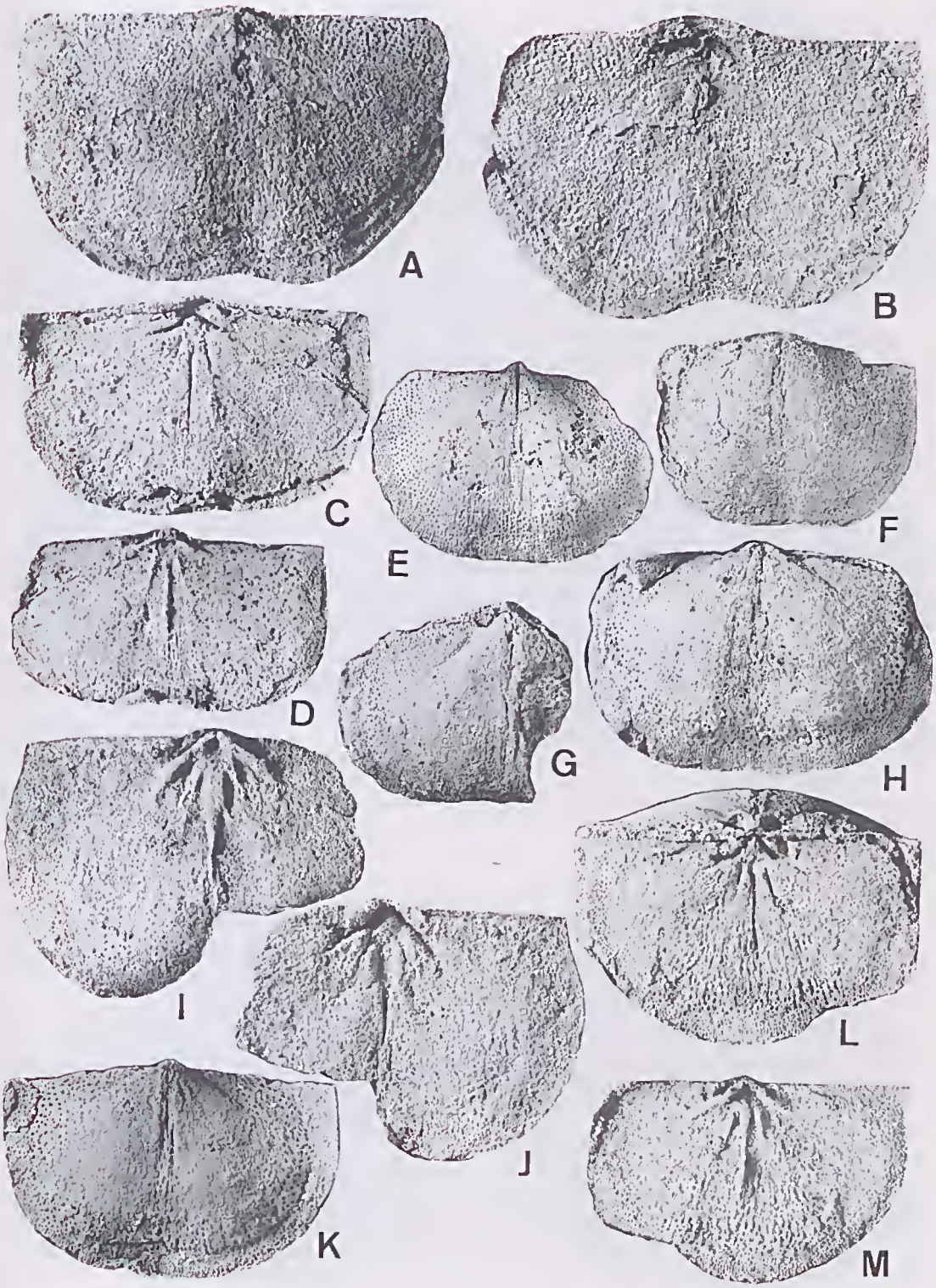
Subfamily RUGOSOCHONETINAE Muir-Wood, 1962

Genus **Neochonetes** Muir-Wood, 1962

Subgenus **Neochonetes (Sommeriella)** Archbold, 1982

Type species. Chonetes prattii Davidson, 1859.

Fig. 2. A–M, *Neochonetes (Sommeriella) magnus* sp. nov. A–B, WAM 69.754, holotype, latex cast of ventral valve external mould and the external mould, ×1.5. C–D, UWA 38552, internal mould of dorsal valve and latex cast from mould, ×1.5. E, UWA 32759, internal mould of ventral valve, ×1.5. F, UWA 31568, internal mould of ventral valve, ×1.5. G, WAM 69.756, internal mould of ventral valve. H, WAM 69.755, internal mould of ventral valve, ×1.6. I–J, UWA 33764, latex cast from mould of dorsal valve interior and the internal mould of dorsal valve, ×1.5. K–M, UWA 31566, internal mould of shell in ventral and dorsal views and latex cast of dorsal interior, ×1.5.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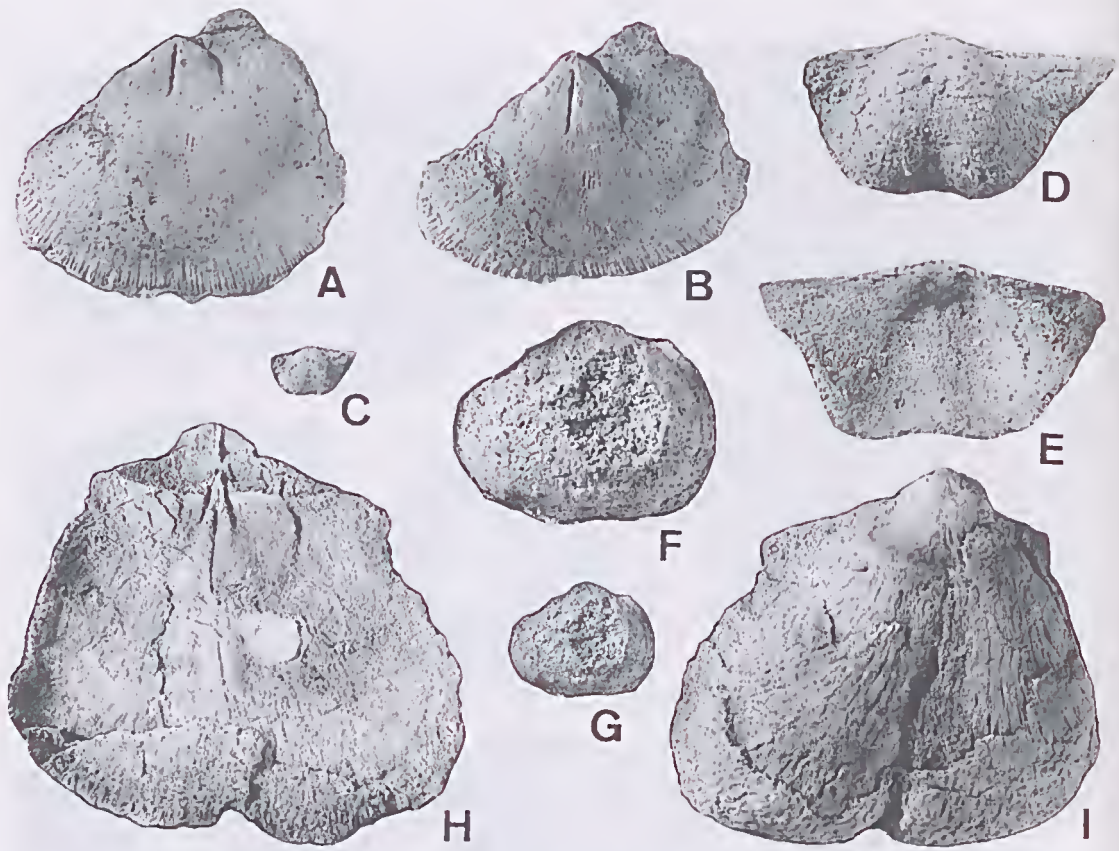


Fig. 3. A, B, *Streptorhychus* sp., WAM 69.753, internal mould of dorsal valve in dorsal and postero-dorsal views, ×1. C–E, *Chonetinella* sp., UWA 33763, latex cast of ventral valve external mould, ×1, ×3.5 and the external mould, ×4. F–G, strophalosiid indet., UWA 32755, internal mould of ventral valve, ×2 and ×1. H, I, *Aulosteges ingens* Hosking 1931, UWA 34433, internal mould of complete shell in dorsal and ventral views, ×1.

Neochonetes (Sommeriella) magnus sp. nov.

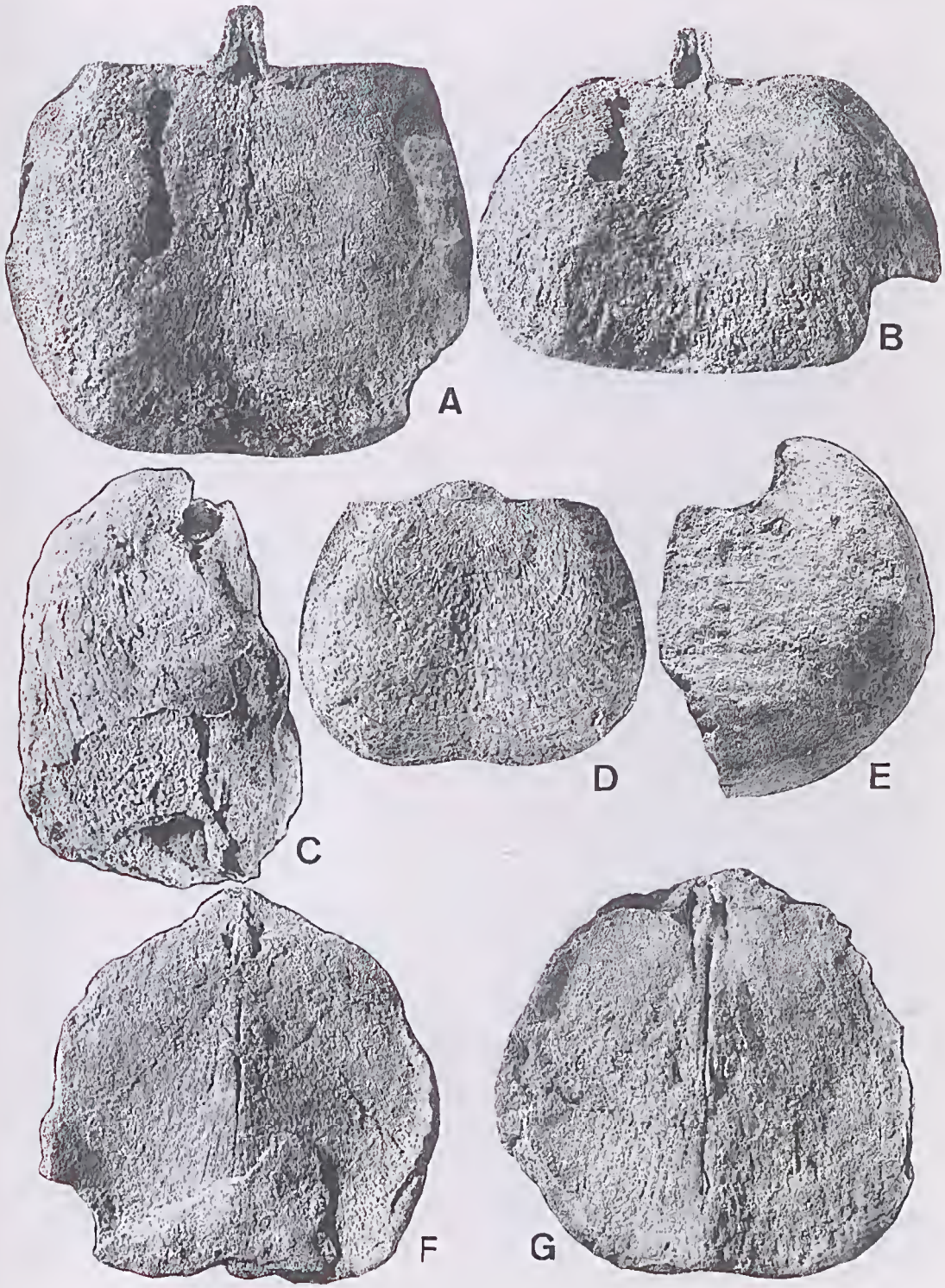
Fig. 2A–M

'Chonetes' sp., Dickins 1957: 2.—Playford 1959: 19.
Neochonetes sp., Playford et al. 1976: 100.
Neochonetes (Sommeriella) sp. nov., Archbold 1988: 46.—Archbold 1993a: 316.
Neochonetes (Sommeriella) sp. nov. A., Skwarko 1993: 91.

Holotype. WAM 69.754, an external impression of a large ventral valve from the High Cliff Sandstone, Woolaga Creek. Source of specimen, H. F. Broadbent, 1963–69, Scotch College Collection No. 179.

Paratypes. WAM 69.755–69.756, two ventral valve internal moulds. UWA 31568, UWA 32755, two ventral valve internal moulds. UWA 38552, UWA 33764, two internal moulds of dorsal valves and UWA 31566 and

Fig. 4. A–G, *Taeniothaerus quadratiformis* sp. nov. A, B, WAM 69.750, external mould of dorsal valve in ventral and antero-ventral views, ×1. C, CPC 34593, internal mould of shell in profile view, ×1. D, CPC 34594, external mould of dorsal valve, ×1. E, UWA 31557, internal mould of ventral valve in profile view, ×1. F, WAM 69.751, internal mould of shell in dorsal view, ×1. G, CPC 34595, internal mould of shell in dorsal view, ×1.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internal mould of a complete shell with valves open at 90°.

Size ranges. Maximum width, 27–44 mm; hinge width, 25–39 mm; shell height, 21–28 mm; length of ventral septum, 11–18.5 mm; length of dorsal septum, 10–13 mm.

Diagnosis. Very large *Neochonetes (Sommeriella)* with relatively flat lateral profile and a weakly developed, broad sulcus.

Description. Convexity of ventral valve usually gentle with shallow sulcus arising close to umbo with a weakly developed median valley. Dorsal valve flat to very gently concave, with no median fold. Greatest width of shell at midlength at maturity. External ornament of weakly developed growth lines, somewhat crowded at anterior of mature specimens. Capillae weakly developed (about 2 per mm at 1.5 cm from umbo on holotype). Interareas very low, marginal spines not known, ventral umbo small, low.

Ventral interior with fine, sharp median septum, up to two-thirds valve height, impressions of parallel vascular trunks weakly impressed. Muscle fields large, flabellate. Teeth small, sharp. Anterior of valve interior finely papillose.

Cardinal process poorly known, apparently internally bilobed. Alveolus prominent and deep at maturity. Median septum sharp, bladelike, arises anteriorly of alveolus, broadens and flattens posteriorly at maturity. Socket ridges distinct, sockets fine, lateral septa distinct, approximately half length of medium septum. Brachial ridges poorly known, weakly developed. Anterior of dorsal valve interior of submature individuals with parallel rows of radiating papillae. Posterior margin of valve smooth.

Discussion. Neochonetes (Sommeriella) magnus is the largest chonetoid known from the Western Australian Permian. The large size and shallow lateral profile of the species, the weakly developed sulcus and the overall flat appearance distinguish this species from all others of the genus.

Neochonetes (Sommeriella) cockbaini Archbold (in Archbold & Shi 1993) from the Jimba Jimba Calcarenite of Early Aktastinian age, is also a large species but possesses a deep, relatively narrow sulcus and a strongly convex ventral profile. *Neochonetes (Sommeriella) tenuicapillatus* Archbold (1981d) from Late Baigendzhinian units of Western Australia possesses very fine capillae and a distinctly concave dorsal valve. The Kungurian *Neochonetes (Sommeriella) afanasyevae* Archbold (1981d) from the Coolkilya Sandstone and correlative units of Western Australia is a smaller species, flattish in appearance but with a narrow dorsal fold.

Genus **Chonetinella** Ramsbottom, 1952

Type species. Chonetes flemingii Norwood & Pratten, 1855.

Comments. Species of *Chonetinella* can approach the morphology of species of *Neochonetes* (see Archbold 1991c: 289). *Chonetinella* is interpreted here as including small rugosochonetids, often subquadrate in outline, with a deep ventral sulcus and fine costellae as for the type species (see Muir-Wood 1962: pl. 9, figs 10–16).

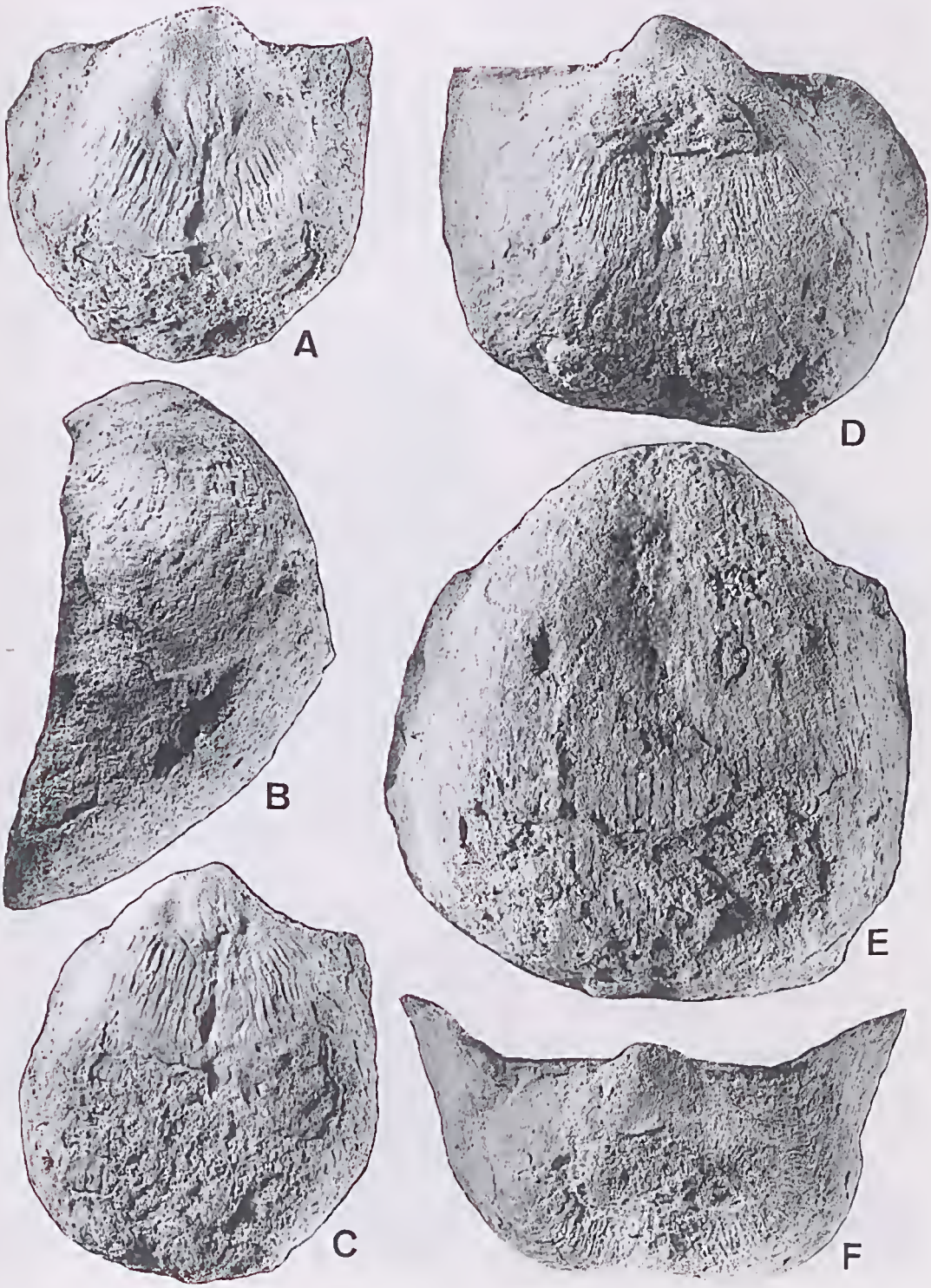
Chonetinella sp.

Fig. 3C–E

Comments. A single external mould of a ventral valve (UWA 33763) of a small chonetid (width, 10.1 mm; height, 6.3 mm) indicates the presence of a second chonetid in the High Cliff fauna. The specimen possesses a prominent sulcus that arises at the umbo. Ears are distinctly demarcated and impart a transverse outline to the valve. Indistinct traces of fine costellae are preserved. The profile of the valve is moderately convex.

The deep sulcus and demarcated ears of the valve, separate the specimen from juvenile *Neochonetes (Sommeriella).* The most strongly sulcate species of *Neochonetes (Sommeriella)* from Western Australia, *Neochonetes (Sommeriella) cockbaini* Archbold (in Archbold & Shi 1993) from the Aktastinian of the Carnarvon Basin, does not develop a distinct, deep sulcus until later in ontogeny, unlike the present specimen.

Fig. 5. A–F, *Taeniothaerus quadratiformis* sp. nov. A, C, CPC 34596, internal mould of shell in postero-ventral and ventral views, ×1. B, UWA 34451, internal mould of ventral valve in profile view, ×1. D–F, WAM 69.749, internal mould of ventral valve in postero-ventral, ventral and posterior views, ×1.1.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This record of *Chonetinella* provides a minor additon to the imperfectly known record of the genus from Western Australia (see also Archbold 1981d). *Chonetinella* is also known from the Early Permian of Irian Jaya (Archbold 1982b, 1991e).

Order PRODUCTIDA Saryeheva & Sokolskaya, 1959

Suborder STROPHALOSIIDINA Waterhouse, 1975

Superfamily STROPHALOSIOIDEA Schuchert, 1913

Family STROPHALOSIIDAE Schuchert, 1913

strophalosiid indet.

Fig. 3F, G

Comments. A single, small internal mould of a ventral valve, UWA 32755, indicates the presence of a strophalosiid in the High Cliff Sandstone assemblage. Traces of an interarea, a small adductor muscle field bisected by a median ridge and a transverse valve outline (width, 17 mm; height, 15 mm) are typical of submature strophalosiids. Lack of external details prevents generic assignment. The specimen is figured for the record.

Suborder PRODUCTIDINA Waagen, 1883

Superfamily AULOSTEGOIDEA Muir-Wood & Cooper, 1960

Family AULOSTEGIDAE Muir-Wood & Cooper, 1960

Subfamily AULOSTEGINAE Muir-Wood & Cooper, 1960

Genus Aulosteges von Helmersen, 1847

Type species. Orthis wangenheimi de Verneuil, 1845 (=*Aulosteges variabilis* von Helmersen, 1847).

Aulosteges ingens Hosking, 1931

Fig. 3H–I

Aulosteges ingens Hosking 1931: 15, pl. 5, figs 1a–c; pl. 6, figs 2a–c.—Coleman 1957 (*partim*): 43, pl. 3, figs 1–4, 6, 8 (*non cet.*).—Archbold et al. 1993: pl. 29, figs 4–7, microfiche 4: 41 (with synonymy).—Skwarko 1993: 91, 98.

Aulosteges cf *ingens*.—Dickins 1957: 2.—Playford 1959: 19.

Aulosteges spinosus.—Coleman 1957 (*partim*): pl. 5, figs 1–3 (*non cet.*).

Aulosteges cf *A. ingens*.—Archbold 1988: 46.

Aulosteges sp. Archbold 1993a: 316.

Lectotype. GSWA 1/5000, a complete worn shell from the Coyrie Formation (*sensu* Skwarko, 1993), =upper part of Madeline Formation (*sensu* Archbold 1993a), Carnarvon Basin.

Comments. Coleman (1957) figured an internal mould of a complete shell from the High Cliff Sandstone as a representative of *Aulosteges spinosus* Hosking (1931), a species with a relatively low ventral interearea, a gently curved ventral profile and based on a small, probably immature, holotype. Coleman's Woolaga Creek specimen UWA 34433, is a form with a distinct, moderately high, triangular, relatively flat ventral interarea, a somewhat twisted ventral umbo, a thin, sharp dorsal median septum and thin, sharp basal ridges of the cardinal process. Flattening of the ventral valve close to the umbo indicates the specimen possessed a cicatrix for attachment. The ventral profile, except for the anterior margin, is relatively flat.

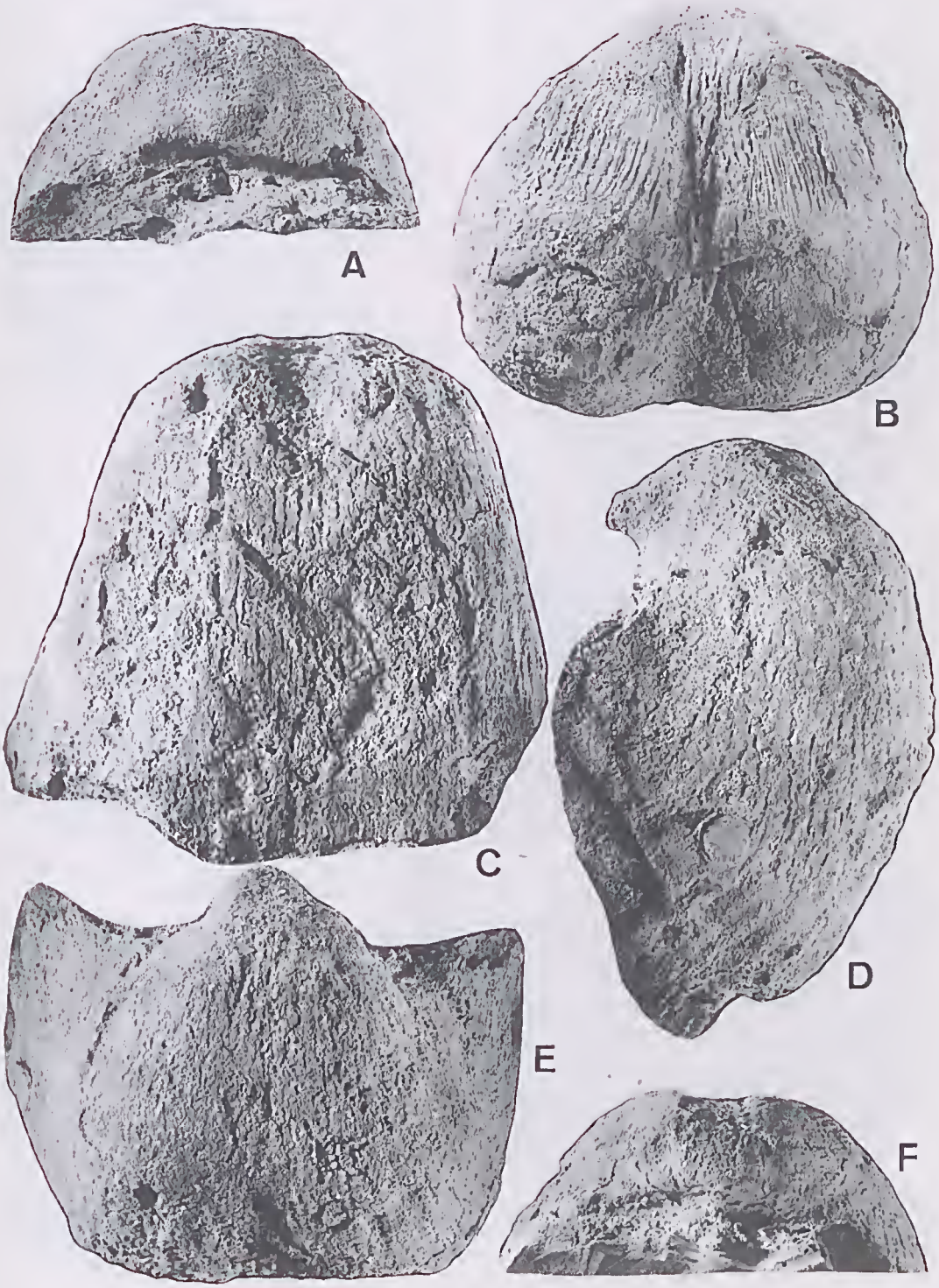
In view of the similarity of the specimen to the holotype of *A. ingens* Hosking, figured by Hosking (1931), Coleman (1957) and Archbold et al. (1993), UWA 34433 is referred to Hosking's species subject to the discovery of large collections which would permit more detailed comparisons.

Genus Taeniothaerus Whitehouse, 1928

Type species. Productus subquadratus Morris, 1845.

Comments. The lectotype of the type species (Natural History Museum, London, BM91171), from the Artinskian of Tasmania, was figured

Fig. 6. A–F, *Taeniothaerus quadratiformis* sp. nov. A, C–E, holotype, UWA 32316a, internal mould of ventral valve in posterior, antero-ventral, profile and postero-ventral valve views, ×1. B, F, UWA 34451, internal mould of ventral valve in postero-ventral and posterior views, ×1.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by Etheridge & Dun (1909), Hill (1950) and Coleman (1957). The type species has been most recently redescribed by Parfrey (1983) and is characterised by a relatively low ventral interarea and a relatively inflated and incurved ventral umbo. The new species described below is retained in *Taeniothaerus* despite possessing a curved interarea of moderate height, because of its large size, inflated and curved ventral profile and external spine features.

Taeniothaerus quadratiformis sp. nov.

Figs 4A–G, 5A–F, 6A–F, 7A–F

Taeniothaerus irwinensis Coleman 1957 (*partim*): 93.
Taeniothaerus sp. cf *T. subquadratus*.—Coleman 1957: 102, pl. 15, figs 8–12.
Taeniothaerus coolkiliensis Coleman 1957 (*partim*): 89, pl. 11, figs 11–12.
Taeniothaerus coolkiliensis.—Playford et al. 1976: 95.
Taeniothaerus sp. nov., Archbold 1988: 46.—Archbold et al. 1993: pl. 32, fig. 6, microfiche 4: 48.—Skwarko 1993: 91.—Archbold 1993a: 316.

Holotype. UWA 32316a, internal mould of mature ventral valve, from about 32 m west of Glendevon Homestead near Woolaga Creek.

Paratypes. WAM 69.750, CPC 34594 and UWA 32043, three external moulds of dorsal valves. CPC 34593, 34595, 34596, WAM 69.751, UWA 32042, 32043, six internal moulds of shells. UWA 31557, 34451, WAM 69.749, three internal moulds of ventral valves.

Size ranges. Measurements are estimates. Width of ventral valve, 49–77 mm; ventral valve height, 57–80 mm; dorsal valve height, 44–63 mm; height of ventral interarea, 5.5–8.5 mm; width of ventral interarea, 25.5–34.5 mm; shell thickness, 25–50 mm.

Diagnosis. Large *Taeniothaerus* with coarse ventral spines, fine dorsal spines, ventral interarea of moderate height for genus and anterior of mature shells with distinct radial crenulations.

Description. Shell large, length slightly exceeds width at maturity, maximum width somewhat anterior of mid-length. Ventral umbo distinct, usually pointed, often overhangs interarea. Ventral valve strongly convex with steep lateral flanks. Sulcus shallow, broad anteriorly, narrow posteriorly, arises close to umbo. Ears small, quadrate to rounded outline. Ventral interarea of moderate height for genus, flat or gently concave (in examples with higher interarea always concave), considerably narrower than width of shell, carries vertical and horizontal striations. Triangular elytridium narrow (up to 2 mm wide on UWA 32043). Ventral spines poorly known but coarse on lateral flanks, up to 1 mm wide.

Dorsal valve concave due to distinct geniculation. Visceral disc weakly convex with low, broad dorsal fold also present on trail. Dorsal valve with spines and dimples. Spines fine over visceral disc (0.3 mm wide), coarser anteriorly (0.5 mm wide). Dimples rounded on visceral disc, elongate on trail. Growth lines fine.

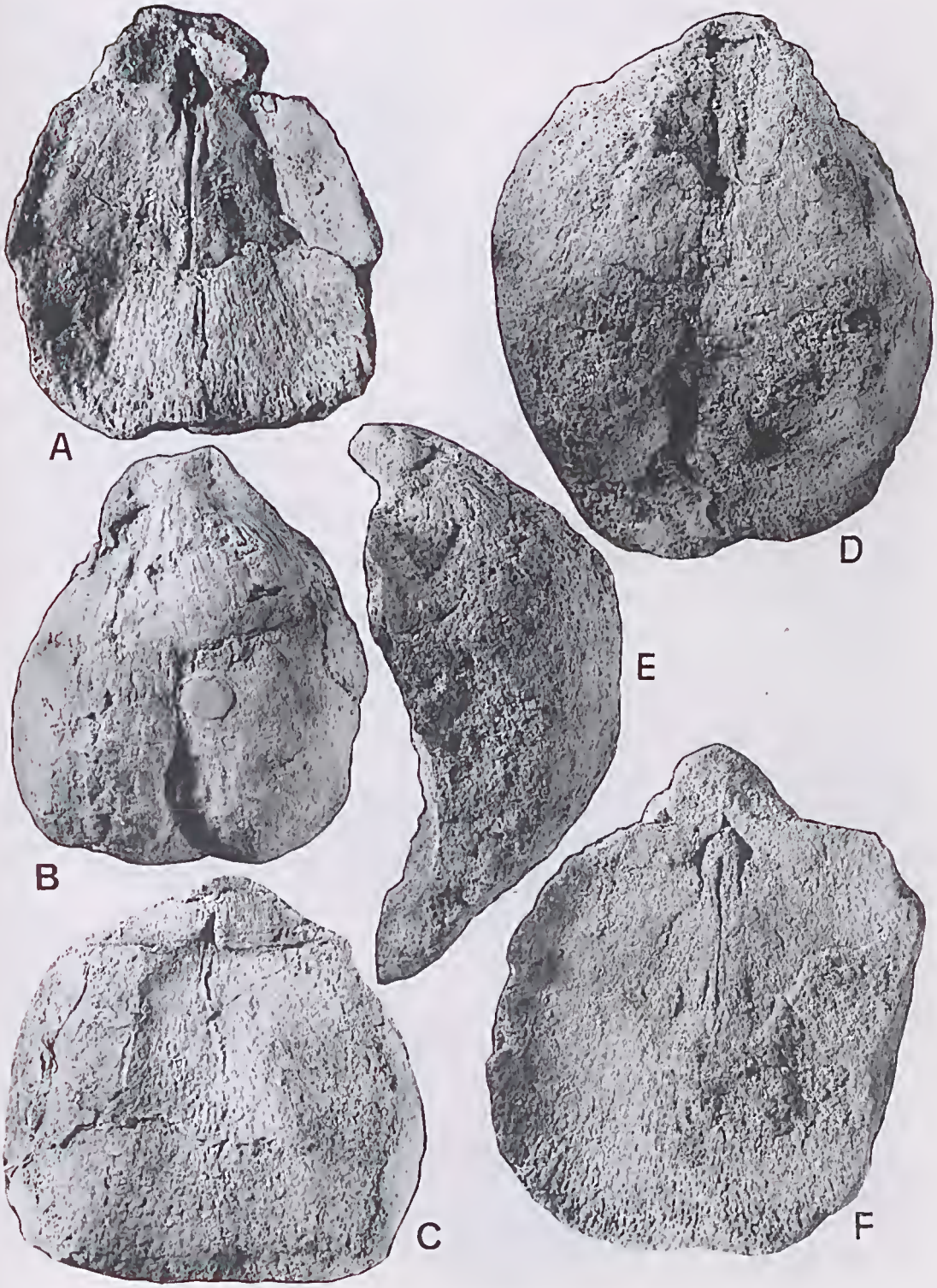
Ventral adductor scars narrow, often on gently raised platform. Diductor scars large, flabellate, strongly striate, deeply impressed.

Cardinal process pronounced, projects ventrally at low angle to visceral disc, trilobed with prominent alveolus at base. Two sub-parallel, low ridges continue anteriorly at base of process at posterior of adductor muscle scars. Brachial ridges absent. Median septum narrow, sharp, extends over three-quarters length of visceral disc in mature shells. Posterior of muscle scars dendritic, anterior essentially smooth.

Comments. Variably preserved specimens of this species were referred by Coleman (1957) to a number of species, including *T. subquadratus* (Morris), depending on their stage of ontogenetic development. Additional material now available permits a revised assessment of the interpretation of the High Cliff species.

Taeniothaerus quadratiformis sp. nov. is a large species distinguished from most Western Australian species referred to *Taeniothaerus* by Coleman (1957) by means of its coarse ventral spines, relative high ventral interarea and details of the ventral sulcus. *T. subquadratus* (Morris, 1845) and its allies from the Artinskian of the eastern Australian Permian (see Parfrey 1983; Waterhouse et al. 1983 and Briggs in Waterhouse 1986b) are a group of large, coarsely spinose species invariably with a low, concave ventral interarea (usually just a few mm high). The dorsal median

Fig. 7. A–F, *Taeniothaerus quadratiformis* sp. nov. A–C, UWA 32043, internal mould of shell in dorsal and ventral views and external mould of dorsal valve with ventral interarea, ×1.2. D–F, UWA 32042, internal mould of shell in ventral, profile and dorsal views, ×1.2.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septum appears to be shorter in the eastern Australian species and the dorsal adductor scars form a more transverse muscle field than that of *T. quadratiformis* sp. nov.

Superfamily LINOPRODUCTOIDEA Stehli, 1954

Family LINOPRODUCTIDAE Stehli, 1954

Subfamily AURICULISPININAE Waterhouse, 1986b

Genus **Costatumulus** Waterhouse, 1983a

Type species. *Auriculispina tumida* Waterhouse, 1983, in Waterhouse et al. 1983.

Costatumulus occidentalis Archbold, 1993

Fig. 8A–L

Linoproductus lyoni.—Coleman 1957 (*partim*): 76, pl. 8, figs 16–19, 22 (*non* 20, 21).
Linoproductus (Cancrinella) cf. *lyoni.*—Dickins 1957: 1.—Playford 1959: 19.
Linoproductus (Cancrinella) sp.—Dickins 1957: 2, 3.—Playford 1959: 19.
Cancrinella sp. cf. *C. lyoni.*—Playford et al. 1976: 98.
Cancrinella sp.—Playford et al. 1976: 98.
Lyonia lyoni.—Archbold 1983 (*partim*): 244.
Cancrinella sp. nov. Archbold 1988: 46.
Cancrinella sp. C.—Archbold et al. 1993, microfiche 4: 65.—Skwarko 1993: 91.
Costatumulus sp. nov. Archbold 1993a: 316.
Costatumulus occidentalis Archbold 1993b: 14, fig. 9A–I.

Holotype. UWA 32025, an internal mould of a complete shell and the external mould of the dorsal valve, from Woolaga Creek, Irwin River Area.

Comments. This species was originally described on the basis of three specimens (Archbold 1993b). Additional material illustrated in Fig. 8 provides details of specific variation that permits a broader understanding of the species.

The outline of the shell is rounded to transverse and the profile distinctly to gently concavo-convex. Ears may be indistinct to distinct. Ventral muscle scars weakly striate at maturity. Ear spines on ventral valve in distinct cluster. Rugae distinct on ventral valve lateral and anterior flanks but poorly developed over venter. Additional specimens confirm that dorsal spines are absent.

Costatumulus occidentalis is a large species, readily distinguished from other Western Australian species (Archbold 1983) by means of its size and details of ornament including weakly developed rugae over the venter and relatively coarse costellae.

Order SPIRIFERIDA Waagen, 1883

Suborder SPIRIFERIDINA Waagen, 1883

Superfamily SPIRIFEROIDEA King, 1846

Family SPIRIFERIDAE King, 1846

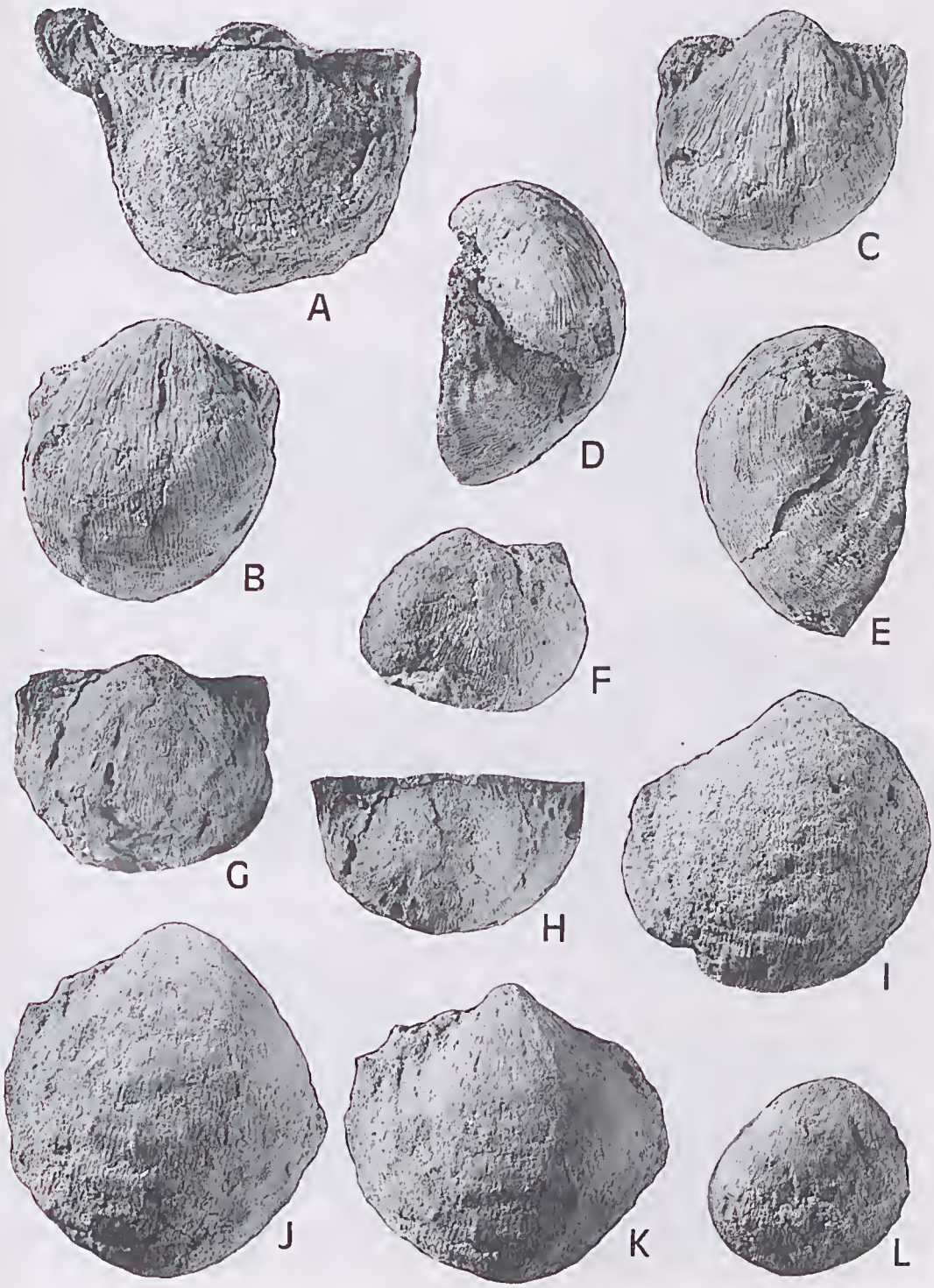
Subfamily NEOSPIRIFERINAE Waterhouse, 1968

Genus **Neospirifer** Fredericks, 1923

Type species. *Spirifer fasciger* von Keyserling, 1846.

Comments. Spiriferids with fasciculate costae are highly diverse during the Late Palaeozoic (eg. see Archbold & Thomas 1985, 1986, 1987) and numerous genera are recognised. Species and genera can demonstrate considerable morphological variability in terms of individual species and species groups within genera. Several distinctive groups (presumably representing incompletely understood 'elines') of *Neospirifer* are known for example in the rich Permian faunas of Western Australia (Archbold & Thomas 1986) and at least one of those is sufficiently well known to designate as a distinct group or subgenus. Recognition of such subgenera appear to be useful in aiding the recognition of palaeobiogeographical subgroupings of related species.

Fig. 8. A–L, *Costatumulus occidentalis* Archbold 1993. A, UWA 32755, external mould of dorsal valve, ×1.2. B–E, UWA 33677, internal mould of complete shell in ventral, postero-ventral and two profile views, ×1.2. F, UWA 32755, internal mould of ventral valve in ventral view, ×1. G, H, UWA 31552, internal mould of ventral valve in ventral and posterior views, ×1. I, UWA 33699, internal mould of ventral valve in ventral view, ×1.2. J, K, UWA 33765, internal mould of ventral valve in ventral and postero-ventral views ×1.2. L, UWA 33697, internal mould of ventral valve in ventral view, ×1.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Subgenus Neospirifer (Neospirifer) Fredericks, 1923

Type species. As for genus.

Comments. The date of authorship of *Neospirifer* by G. N. Fredericks is normally given as 1924 (see Archbold & Thomas 1984), the year when volume 38, number 3 of the Izvestiya of the Geologicheskogo Komiteta was published in Petrograd. Volume 38 of the journal was actually issued for the year 1919 but like many issues of the Izvestiya during the 1920s, was published some years later with individual numbers of the volume being issued out of sequence. It is of note that volume 39, number 2 of the Izvestiya, which contains a summary report of activities of the Geologicheskogo Komiteta for 1919 was published in 1923 in Peterburg. Within the summary report is a summary of G. N. Fredericks' theoretical studies the full text of which was later published in 1924 as his 'Paleontologicheskie Etyudy' in number 3 of volume 38. Within this summary, many of his new genera are listed with type species and brief diagnoses. One such genus is given as 'Neospirifer Frks—shell ribbed—plicate, Type: *Spirifer fasciger* Keys.;' which satisfies the criteria of publication for the date in question, ie. 1923. This date of publication of *Neospirifer* is used herein and the authorship is ascribed to G. N. Fredericks (cited as Fredericks 1923 in the references).

Neospirifer (Neospirifer) sp.

Fig. 14A

Comments. Specimen WAM 69.760, an external mould of a ventral valve, possessing fine costae and distinct growth lines resulting in a tegulate micro-ornament, is referred to *Neospirifer (Neospirifer)*. The specimen carries up to 6 pairs of relatively low lateral plications (including the sulcal bounding pair). The sulcus is relatively shallow, broadens anteriorly and possesses a pair of plications on its inner lateral flanks. The specimen is transverse (85 mm wide) and growth lines indicate a lack of attenuated ears or truncated hinge. In view of these morphological details it appears unlikely that the specimen is referable to *Neospirifer (Quadrospirifer)* subgen. nov. as described below.

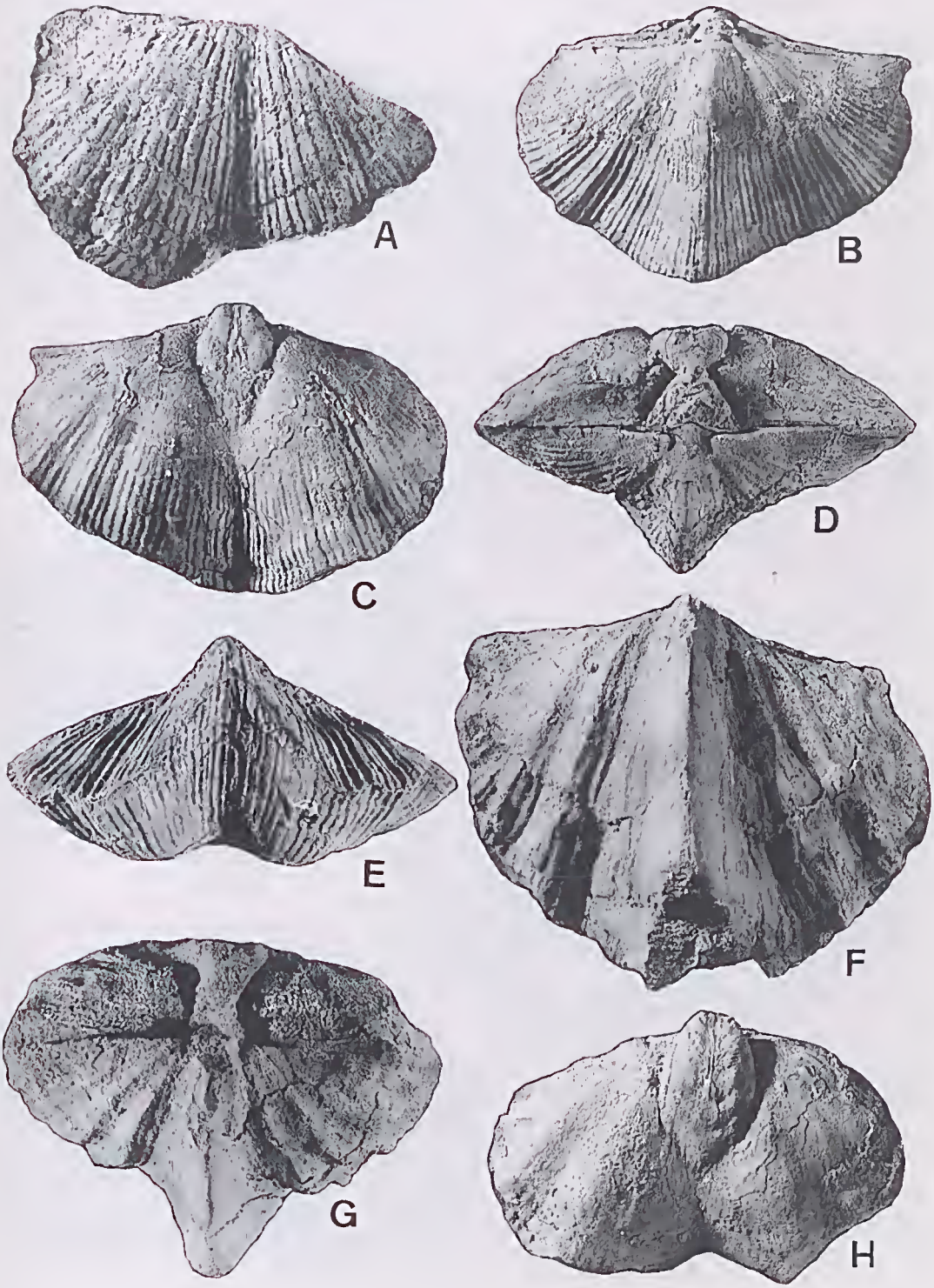
Neospirifer (Quadrospira) subgen. nov.

Type species. Neospirifer plicatus Archbold & Thomas, 1986.

Diagnosis. Medium to large *Neospirifer* with well-developed sulci and fastigia, low to prominent lateral plications and truncated hinge line and interareas at maturity with attenuated ears.

Discussion. In the Western Australian Early Permian, a distinctive group of species ranging in age from Sterlitamakian to Latest Baigendzhinian includes the species *Neospirifer hardmani* (Foord), *Neospirifer plicatus* Archbold & Thomas and *Neospirifer postplicatus* Archbold & Thomas. These species all possess truncated hinge lines and interareas at maturity and hence possess attenuated ears. The anterior fold is high, the fastigium pronounced and the sulcus distinct. Archbold & Thomas (1986) noted that these Westralian species shared these morphological features with a group of Permian species found throughout the Early and Late Permian of the Cimmerian Province as defined by Archbold (1983a). A current list of many of these records includes: *N. hardmani* as recorded by Hudson & Sudbury (1959), Sterlitamakian, Arabia; *Aperispirifer undatus* as recorded by Termier et al. (1974), Sterlitamakian, Afghanistan; possibly *Neospirifer triuncnsis* (Reed, 1944), late Early Permian, Pakistan; *N. timorensis* (Martin, 1881; see also Archbold & Bird 1989), Permian, Timor; *Neospirifer* sp. (Garson et al. 1975), Early Permian, Peninsular Thailand; *Neospirifer* sp. nov. (Archbold et al. 1996), Aktastinian, Badhaura, India; and the Late Permian *Neospirifer tibetensis* Ting (1962; see also Yang & Zhang 1982) from southern Tibet and *Neospirifer kubeiensis* of Fang & Fan (1994) from Western Yunnan. All the above records are now referred to *Neospirifer (Quadrospira)*.

Fig. 9. A–H, *Neospirifer (Quadrospira) woolagensis* sp. nov. A, UWA 33743, latex cast of ventral valve external mould, ×1.2. B–E, UWA 34296, internal mould of shell in dorsal, ventral, posterior and anterior views, ×1. F, G, UWA 34294, holotype, internal mould of shell in dorsal and posterior views, ×1. H, UWA 31584, internal mould of ventral valve, ×1.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Neospirifer (Quadrospira) woolagensis sp. nov.

Figs 9A–H, 10A–E, 11A–F

Neospirifer sp. nov. A.—Dickins 1957: 2.—Playford 1959: 19.—Playford et al. 1976: 100.
Neospirifer sp. nov. Archbold 1988: 46.—Skwarko 1993: 91.—Archbold 1993a: 316.

Holotype. UWA 34294, an internal mould of a complete shell.

Paratypes. UWA 34296, 34311, 31581, three internal moulds of complete shells. UWA 33743, an internal mould of a shell with external mould of the ventral valve. UWA 31584, 38582, two internal moulds of ventral valves. CPC 34597, 34598, two incomplete internal moulds of shells.

Size ranges. Hinge width, 52–67 mm; maximum width, 62–71 mm; ventral valve height, 44–66 mm; dorsal valve height, 39–53 mm; thickness, 31–50 mm.

Diagnosis. Large *Neospirifer (Quadrospira)* with pronounced anterior fold, high fastigium, pronounced lateral plications at maturity and strong, relatively coarse but equidimensional costae.

Description. Large sized species, subquadrate and inflated at maturity, maximum width at approximately shell mid-length. Ears attenuated and interareas truncated at maturity.

Ventral umbo small, pointed, incurved, overhangs interarea. Sulcus broad, deep, U-shaped cross-section. Sulcal tongue long, inclined at 90° to plane of commissure. Three pairs of plications (including sulcal bounding pair) developed on ventral lateral flanks. Plications rounded to sharp. Costae moderately coarse (up to 1.0 mm wide at 3 cm from umbo, 1.5 mm wide at 5 cm from umbo) with narrow interspaces.

Delthyrium prominent. Dental plates strong, flanges stout and thickened, adminicula buried in valve thickening at maturity. Muscle field broad, rounded, adductor scars vertically striated, diductor scars with radial striations.

Dorsal fastigium high, anterior fold prominent. Lateral plications and costae as for ventral valve. Dorsal interarea low, cardinal process distinct, wider than long and vertically striated. Delicate myophragm bisects muscle field. Socket and crural plates typical of genus.

External micro-ornament poorly known, traces of radial capillae and distinct growth lines rarely preserved.

Discussion. The very pronounced fastigium, generally strong lateral plications and nature of the fold and sulcal tongue ally *N. (Q.) woolagensis* sp. nov. with *N. (Q.) plicatus* Archbold & Thomas (1986) from the Early Baigendzhinian of the Madeline Formation, Western Australia and *N. (Q.) timorensis* (Martin, 1881) from an unknown horizon, Timor. Both those species, however, possess fine costae and *N. (Q.) timorensis* possesses an additional pair of lateral plications.

Genus Occidalia gen. nov.

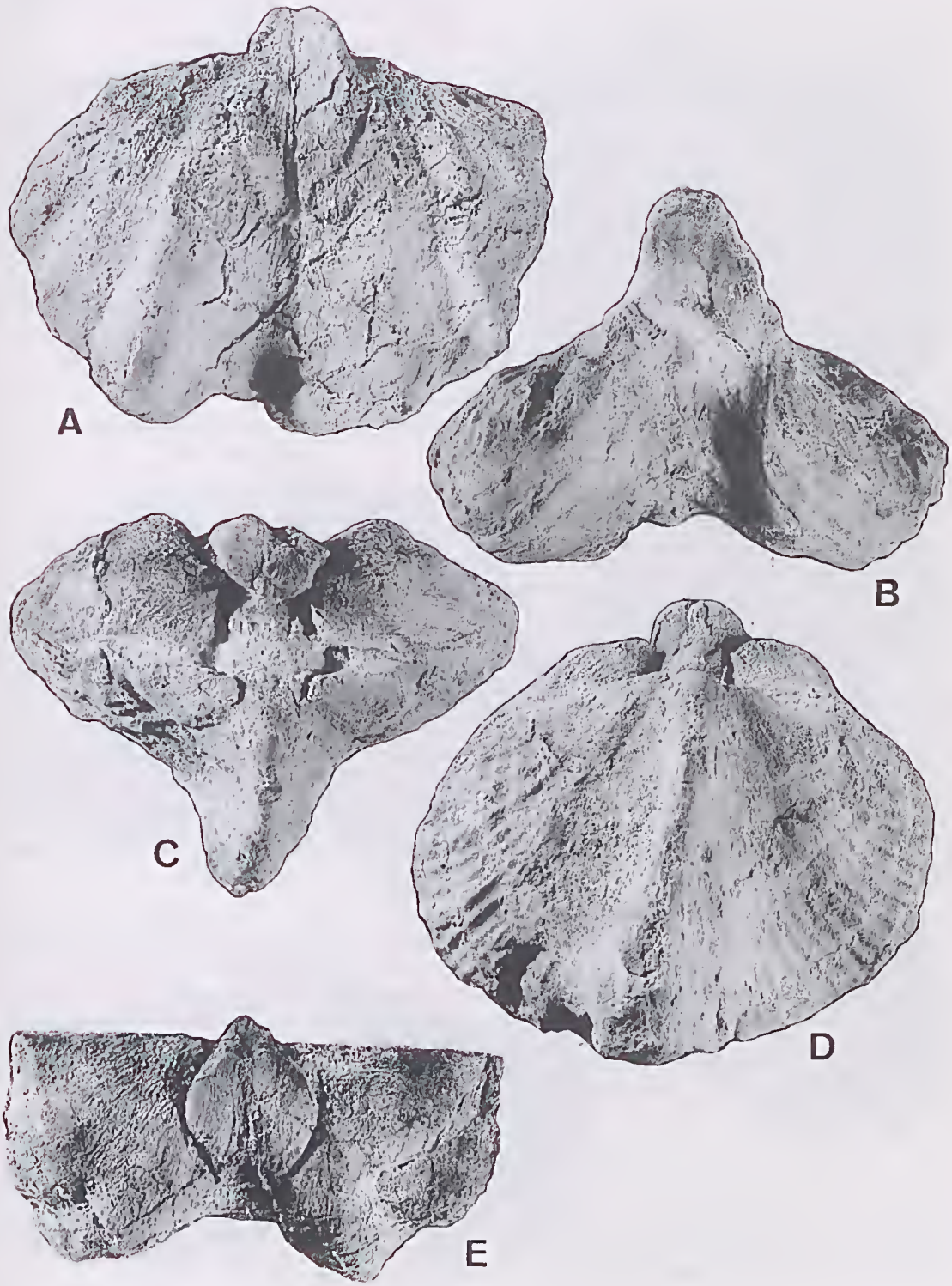
Type species. Occidalia shahi sp. nov.

Diagnosis. Moderately to strongly plicate transverse neospiriferids with high, sharp fastigia and pronounced anterior fold. Maximum width at hinge line. Sulcal tongue pronounced, at close to 90° to the plane of the commissure.

Discussion. This new genus was foreshadowed by Archbold (1996) when describing the somewhat less well known species *Crassispirifer mingenewensis* (see Archbold 1996: p. 36, fig. 10A–L). The Mingenew Formation species is now referred to *Occidalia* as is the species figured by Archbold et al. (1996) as *Crassispirifer* sp. nov. from the Aktastinian Badhaura Formation of Rajasthan, peninsular India.

Crassispirifer Archbold & Thomas (1985) is a closely related genus with lower lateral plications and broad, rounded fastigia and anterior fold of moderate height. Its sulcal tongue is distinct and at approximately 45° to the plane of the commissure. Both *Crassispirifer* and *Occidalia* may be descended from a smaller species such as *Crassispirifer condoni* Archbold & Shi (1993) from the Jimba Jimba Calcarenite (or upper Callytharra Formation in the extended sense of Mory 1996).

Fig. 10. A–E, *Neospirifer (Quadrospira) woolagensis* sp. nov. A, UWA 34294, holotype, internal mould of shell in ventral view, ×1.2. B–D, UWA 34311, internal mould of shell in anterior, posterior and dorsal views, ×1. E, UWA 38552, internal mould of ventral valve in postero-ventral view, ×1.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Occidalia shahi sp. nov.

Figs 12A–K, 13A–I

Neospirifer sp. nov. B, Dickins 1957: 2.—Playford 1959: 19.—Playford et al. 1976: 100.
neospiriferid gen. et sp. nov., Archbold 1988: 46.—Archbold 1993a: 316.

Holotype. UWA 34309, an internal mould of a shell and external mould of dorsal valve with ventral umbo and interarea region.

Etymology. For Shri Sumtilal C. Shah, retired Deputy Director of the Geological Survey of India and collector of the *Occidalia* species from Badhaura, India.

Paratypes. UWA 34310, internal mould of dorsal valve. UWA 33690, 34308, 33691, three internal moulds of shells. UWA 33754, internal mould of ventral valve.

Size ranges. Estimates only, due to preservation of material. Maximum width, 75–90 mm; ventral valve height, 35–42+ mm; dorsal valve height, 25–35 mm.

Diagnosis. Moderately plicate *Occidalia* with high, sharp fastigium, prominent fold and sulcal tongue close to 90° to the plane of the commissure.

Description. Moderate sized species, biconvex, transverse, maximum width at hinge line.

Ventral umbo small, sharp, arched over delthyrium. Interarea low, striated horizontally (growth lines) and, less regularly, vertically (denticular grooves). Delthyrium distinct, delthyrial grooves and ridges present. Sulcus arises at umbo, broadens anteriorly to incorporate first pair of plications. Sulcal tongue prominent, orientated close to 90° to plane of commissure. Lateral plications distinct, moderately low, up to five pair on valve flanks. Fasticulation of costae distinct, up to five costae per bundle. Costae sharp, equidimenstional, intercostal valleys narrow.

Dorsal umbo small, sharp, pointed; interarea very low. Fastigium arises at umbo, remains sharp, narrow, high, crest delineated by single costa. Anterior fold high, rounded but sharp crested. Lateral plications and fasciculate costae as for ventral valve.

External micro-ornament of growth lamellae giving tegulate appearance, with rare traces of radial capillae.

Ventral teeth stout with thickened dental flanges and adminicula. Ventral muscle field prominent, typically neospiriferid. Dorsal socket plates stout, cardinal process typically spiriferid.

Discussion. Occidalaia shahi sp. nov. is close to *Occidalia mingenewensis* (Archbold, 1996) from the Baigendzhinian Mingenew Formation, Perth Basin. The Mingenew species is differentiated by means of its more prominent lateral plications and longer sulcal tongue resulting in a higher dorsal fold. The new species from the Badhaura Formation, India (see Archbold et al. 1996: fig. 3J, L) possesses a rounded anterior dorsal fold and coarser, fewer costae than the Western Australian species.

Superfamily SYRINGOTHYRIDOIDEA Fredericks, 1926

Family SYRINGOTHYRIDIDAE Fredericks, 1926

Subfamily PERMOSYRINXINAE Waterhouse, 1986

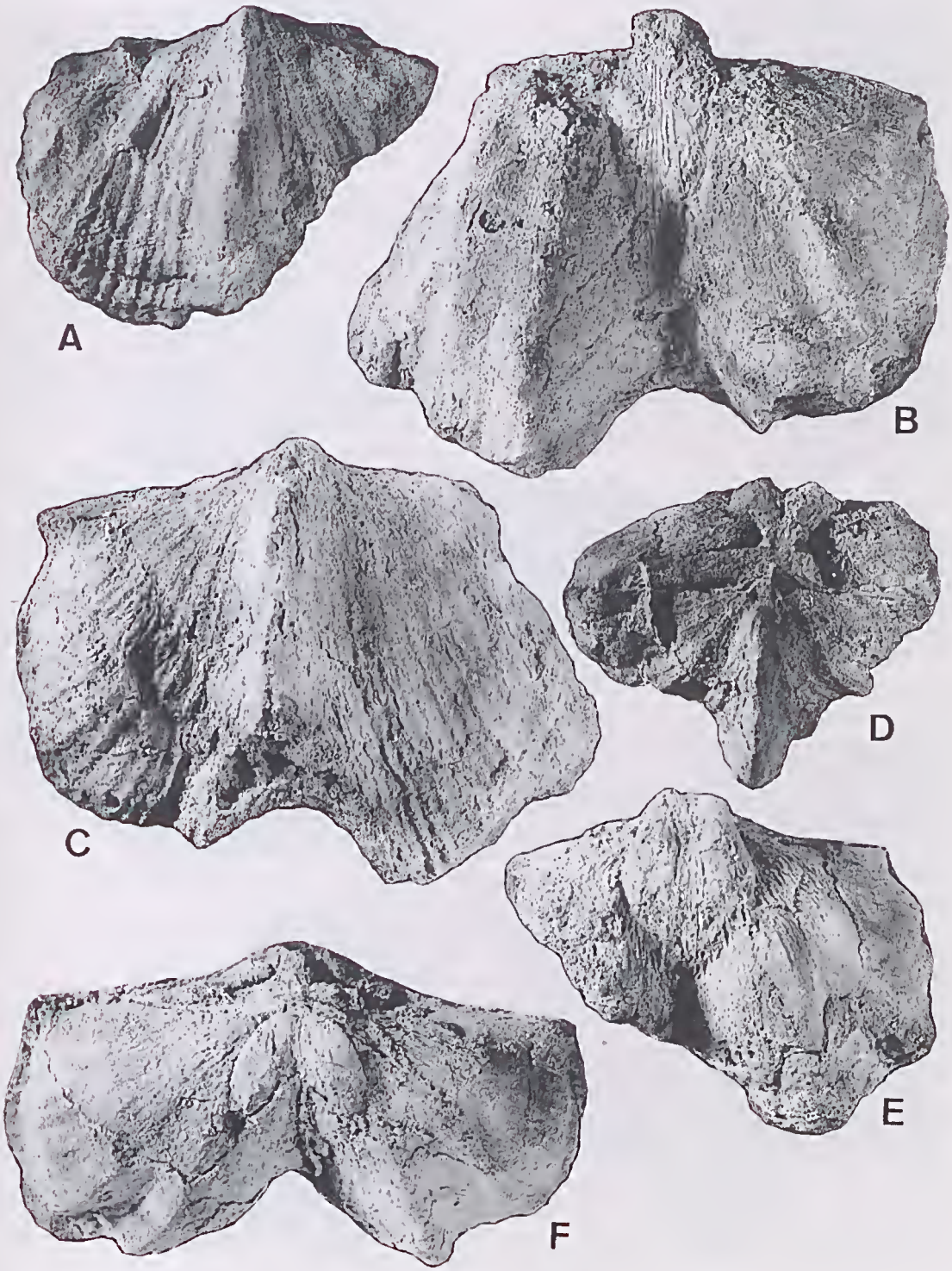
Genus **Woolagia** gen. nov.

Type species. Woolagia playfordi sp. nov.

Diagnosis. Transverse permosyrinxinid, normally with distinct broad groove in dorsal fastigium flanked by pair of low costae. Ventral sulcus shallow, deepens anteriorly at maturity, smooth or with low inconspicuous pair of costae on flanks. Costae simple on lateral flanks.

Discussion. A large and variable collection of specimens from the High Cliff Sandstone indicates the presence of a distinctive permosyrinxinid in the fauna. Many specimens are highly transverse while others grade to a somewhat less transverse outline at maturity. All possess typical spiriferid ventral muscle scars with simple, short ventral dental plates (flanges and adminicula thickened with no syrinx, additional septa or other structures).

Fig. 11. A–F, *Neospirifer (Quadrospira) woolagensis* sp. nov. A, D, E, CPC 34597, incomplete internal mould of shell in dorsal, posterior and ventral views, ×1. B, C, UWA 31581, internal mould of shell in ventral and dorsal views, ×1.2. F, CPC 34598, internal mould of shell in postero-ventral view, ×1.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The Permosyrinxinae are abundant in the cool and temperate Permian brachiopod faunas of the world (eg. see Grigoreva et al. 1989; Waterhouse 1987; Archbold 1996) but the genus *Woolagia* appears distinctive when compared with other genera reviewed and discussed by Waterhouse (1987).

Woolagia playfordi sp. nov.

Figs 14H–Q, 15A–Y

Spiriferidae sp. nov., Dickins 1957: 2.—Playford 1959: 19.—Playford et al., 1976: 100.
Punctocyrtella sp. nov. Archbold 1988: 46.
Cyrtella? sp. nov. Archbold 1993a: 316.

Holotype. UWA 34285e, an internal mould of a complete shell.

Etymology. Named for Prof. G. Playford, collector of much of the type material.

Paratypes. UWA 34285e, 33762, 33688, 33760, 34386, 34285h, six internal moulds of shells. UWA 38552, 31785, GSWA 49479, three internal moulds of ventral valves. UWA 33761, GSWA 49477, two ventral valve external moulds. GSWA 49476, UWA 34286, two external moulds of dorsal valves. UWA 33760, internal mould of dorsal valve. GSWA 49478, internal mould of dorsal valve and external counterpart.

Size ranges. Maximum width, 41–56 mm; ventral valve height, 14–28 mm; dorsal valve height, 13–24 mm; ventral interarea height, 5.0–5.5 mm. Some measurements are estimates due to preservation.

Diagnosis. Moderately to strongly transverse shells with broad dorsal fastigial groove flanked by pair of low costae. Sulcus may have weakly developed pair of costae. Costae simple. Ventral muscle field typically spiriferid.

Description. Transverse, invariably spindle shaped shells with low interareas. Ventral posterior moderately thickened with ventral muscle field projecting posteriorly into shell thickening. External ornament of simple costae, up to 10 pairs on dorsal and ventral lateral flanks of internal moulds (costae not visible on outer lateral flanks of internal moulds) whereas up to 20 costae on ventral lateral flanks on external moulds.

Dorsal fastigium distinct with broad median groove usually flanked by pair of broad, low, rounded costae. Anterior fold prominent, rounded. Ventral sulcus well rounded in cross-section, with short anterior sulcal tongue, which arises at umbo, carries one pair of low, indistinct costae on its lateral slopes.

Ventral interior with thick, delthyrial plate. Interarea apsacline, relatively low, horizontally striate. Dental plates strong, stout, adminicula thickened but short. Ventral muscle field equidimensional to slightly elongate. Adductor scars narrow, occupy centre of muscle field. Diductor scars weakly striate. Delicate, blade-like median myophragm rarely present in centre of muscle field. Dorsal interior with wide, short, thickened socket plates and typical spiriferid cardinal process. Delicate median myophragm may extend for half valve length.

Micro-ornament of delicate radial grooves. Pits and pustules not known. Punctae not confirmed.

Discussion. The nature of the dorsal fastigium, the short ventral adminicula and the lack of complex ventral delthyrial structures indicate the distinctiveness of *Woolagia playfordi* sp. nov. Relatively small specimens referred to *Primorewia reshetnikovi* by Pavlova (in Pavlova et al. 1991: pl. 31, figs 1–3), from the Kungurian of southern Mongolia, possess comparable costae, transverse outline and micro-ornament to *Woolagia playfordi* but ventral adminicula of the Mongolian specimens appear to be longer and surround the posterior of the ventral muscle field.

Genus Cyrtella Fredericks, 1924

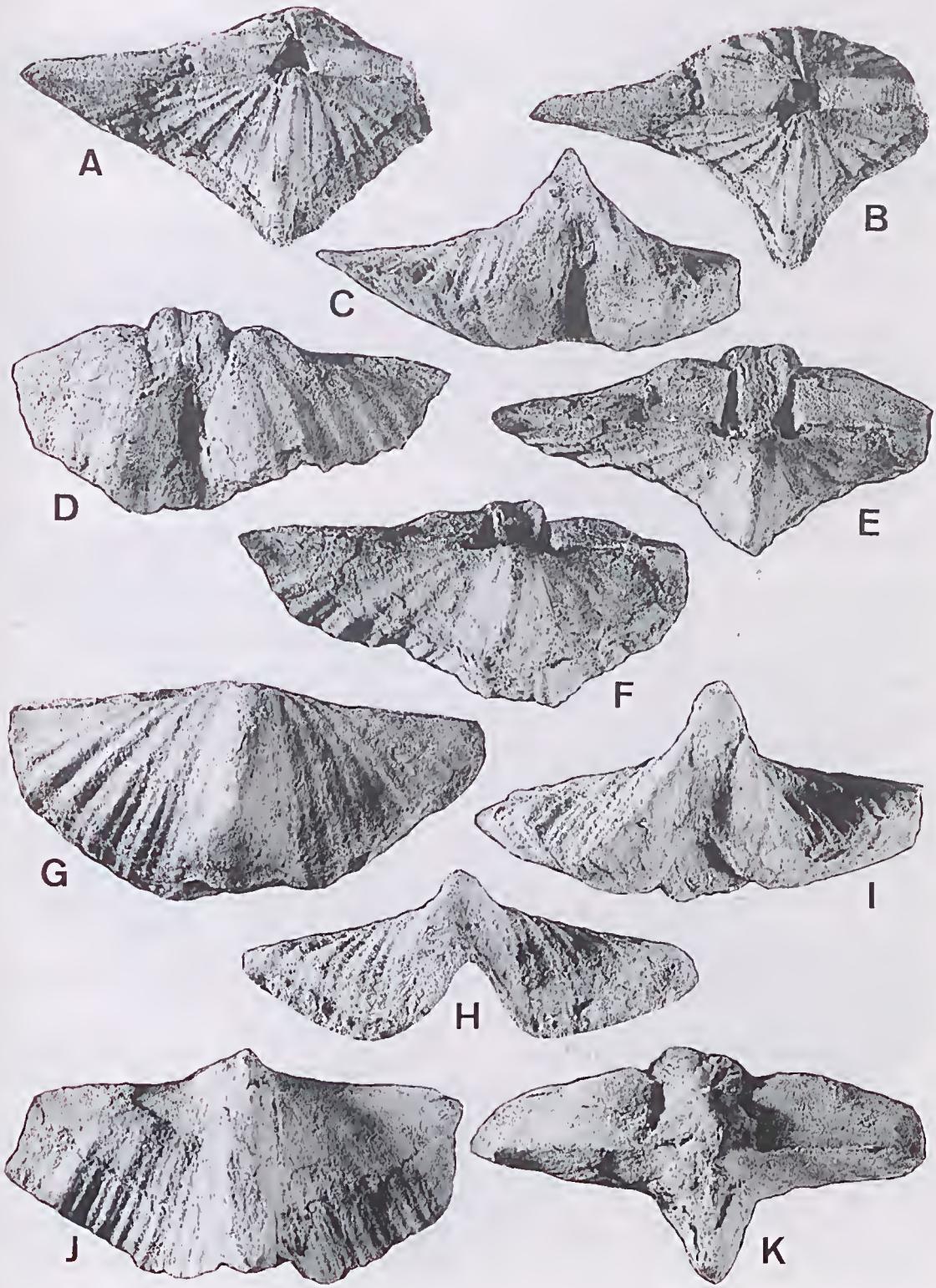
Type species. Cyrtia kulikiana Fredericks, 1916.

?Cyrtella sp.

Fig. 14B–G

Comments. Two specimens (CPC 34599, an in-

Fig. 12. A–K, *Occidalia shahi* gen. et sp. nov. A–F, UWA 34309, holotype, latex cast of external mould of dorsal valve in dorsal and postero-dorsal views, ×1, internal mould of shell in anterior, ventral, posterior and dorsal views, ×1. G, H, UWA 34310, internal mould of dorsal valve in dorsal and anterior views, ×1. I–K, UWA 33690, internal mould of shell in anterior, dorsal and posterior views, ×1.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ternal mould of a shell with counterpart external mould of dorsal valve and WAM 69.760a an external mould of a ventral valve) indicate the presence of a larger permosyrinxinid within the High Cliff fauna. The specimens indicate a form with a smooth V-sided sulcus, relatively low ventral interarea, smooth dorsal fastigium with virtually no central groove and strong, simple costae on the lateral flanks of both valves. Ventral adminicula are long and relatively fine (hence unlike those of *Woolagia playfordi*) and the ventral muscle field does not project posteriorly into ventral valve thickening.

Whether or not the specimens should be referred to *Cyrtella* is debatable, although that genus can be interpreted broadly (Waterhouse 1987) to include species with low ventral interareas. The specimens are figured for the completeness of illustrating the High Cliff fauna.

Family INGELARELLIDAE Campbell, 1959

Subfamily INGELARELLINAE Campbell, 1959

Comments. The family Ingelarellidae is now considered to include three subfamilies (Clarke 1992; Carter et al. 1994). Only the Ingelarellinae are reliably known outside the Permian of the Australazean Province.

Genus **Tomiopsis** Benediktova, 1956

Type species. *Brachythyris kumpani* Yanishevskiy, 1935.

Comments. Of the Ingelarellinae, only *Tomiopsis* is reliably known from the Permian of Western Australia (Archbold & Thomas 1986a). *T. rarus*, from the High Cliff Sandstone, is the only Western Australian species for which the distinctive micro-ornament of the genus is not yet known (see Arehbold & Thomas 1986a; Archbold 1993b).

Tomiopsis rarus Archbold & Thomas 1986a

Fig. 15Z, AA

'Martiniopsis' sp. A, Dickins 1957: 2.—Playford 1959: 19.—Playford et al. 1976: 100.

'Martiniopsis' sp. A?, Dickins 1957: 2.

Ingelarella branxtonensis.—Runnegar 1969: 88, pl. 1, figs 6–8 (*non cet.*).

Tomiopsis rarus Archbold & Thomas 1986a: 590, fig. 4—1–5.—Archbold 1988: 47.—Archbold et al. 1993: 254, pl. 43, figs 16–20, microfiche 5: 105.—Archbold & Shi 1995: 210, fig. 4—10, 11.

Ingelarella plana.—Dickins 1970: 22.

Comments. An incomplete internal mould of a ventral valve (UWA 38552) possesses the characteristic low lateral plicae and broad, moderately gentle sulcus of *Tomiopsis rarus* Archbold & Thomas (1986a), a species originally based on a single internal mould of a complete shell. The specimen is a submature individual with thin, diverging ventral adminicula (approximately 40°) and is an internal mould of an unthickened valve.

Order ATHYRIDIDA Dagys, 1974

Supermfamily ATHYRIDOIDEA McCoy, 1844

Family ARTHYRIDIDAE McCoy, 1844

Genus **Cleiothyridina** Buckman, 1906

Type species. *Atrypa pectinifera* Sowerby, 1840.

Cleiothyridina perthensis sp. nov.

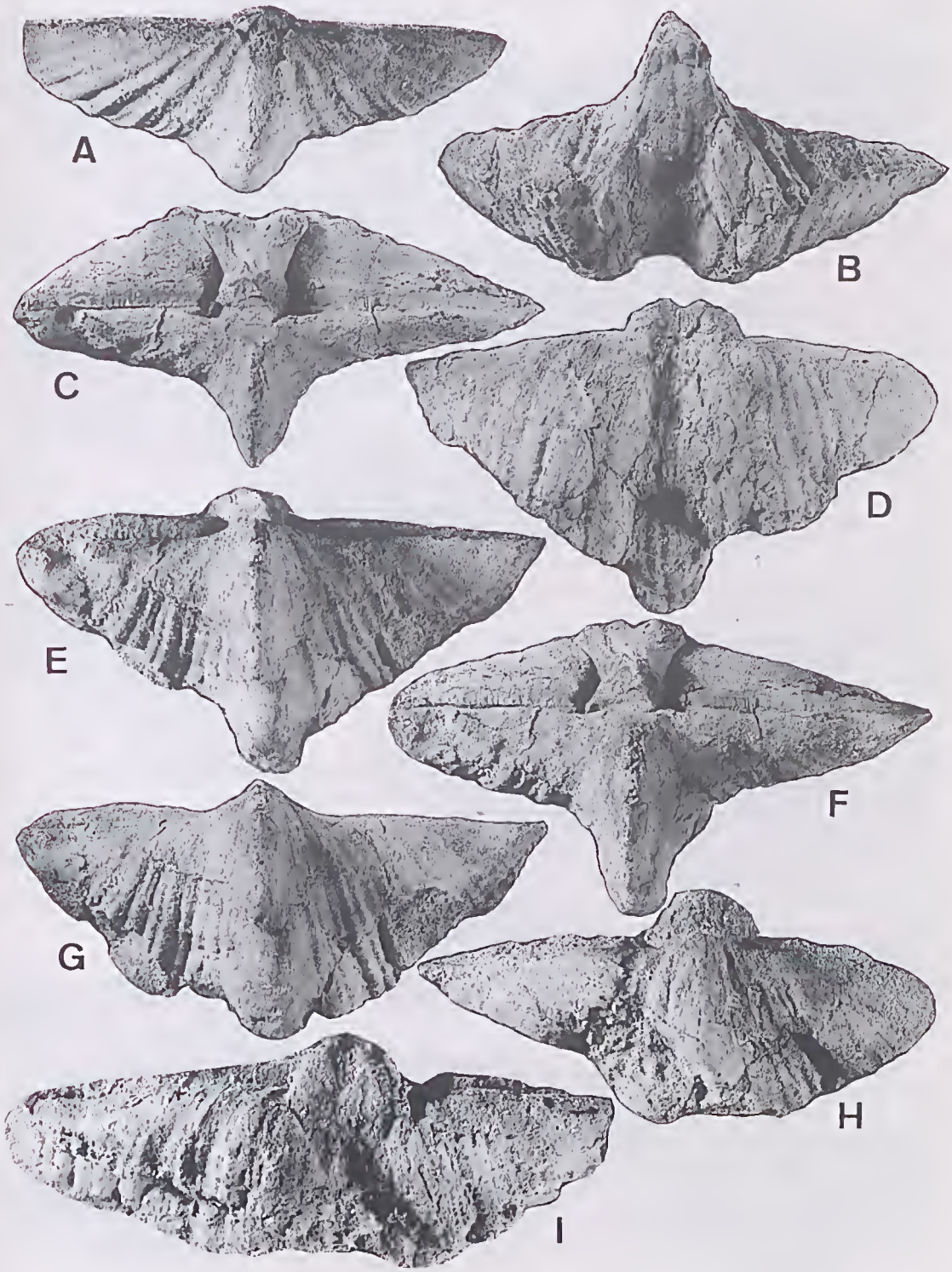
Fig. 16A–P

Cleiothyridina sp. Dickins 1957: 2.—Playford 1959: 19.—Playford et al. 1976: 100.—Archbold 1988: 47.—Skwarko 1993: 92.—Archbold 1993a: 316.

Holotype. UWA 31563, a complete internal mould of a conjoined shell.

Paratypes. GSWA 49480, external mould of posterior of shell, GSWA 49481, UWA 33366, 32753, 33761, 32755, 38552a, 31554, seven internal moulds of complete shells.

Fig. 13. A–I, *Occidalia shahi* gen. et sp. nov. A, UWA 34310, internal mould of dorsal valve in posterior view, ×1. B–G, UWA 34308, internal mould of shell in anterior, posterior, ventral, dorsal, postero-dorsal and antero-dorsal views, ×1. H, UWA 33754, internal mould of ventral valve, ×1. I, UWA 33691, internal mould of shell in dorsal view, ×1.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Size ranges. Maximum width, 25–34 mm; ventral valve height, 21–27 mm; dorsal valve height, 19.5–28 mm; thickness, 12–17 mm.

Diagnosis. Medium sized *Cleiothyridina*, transversely oval outline, biconvex at maturity. Robust and thick at maturity.

Description. Juveniles plano-convex, mature specimens biconvex. Outline transversely oval at maturity, maximum width close to mid-length. Mature shells relatively robust with thick profile.

Ventral valve flat in juvenile specimens, gently convex at maturity. Ventral umbo erect with apparently small foramen. Mature specimens with weakly developed sulcus anteriorly, resulting in weakly uniplicate commissure. Dorsal valve strongly convex, enhanced by very weakly developed median fastigium.

Exterior poorly known but growth lamellae well developed—spines unknown.

Ventral teeth short, thickened with dental plates fused into umbonal walls. Ventral muscle field large. Adductor scars posteriorly located with ridge extending anteriorly, bisecting the diductor scars. Diductor scars weakly striated or smooth, demarcated from valve floor by low, semi-circular ridge.

Dorsal interior with variably developed median septum. Muscle scars weakly impressed, valve floor variably striate.

Discussion. Most species of *Cleiothyridina* described by Etheridge (1889, 1903) and Foord (1980) from the Early Permian of Western Australia require modern description. This is being undertaken by the present author. Only *Cleiothyridina ovalis* Shi (in Archbold & Shi 1993) has received modern study. *Cleiothyridina perthensis* sp. nov. is distinguished from other Western Australian early Permian species by means of its robust, thick profile, virtually absent ventral sulcus, feebly uniplicate anterior margin and biconvex profile at maturity.

Genus **Composita** Brown, 1849

Type species. Spirifer ambiguus Sowerby, 1823.

Composita sp.

Fig. 16Q–W

Comments. Grant (1976: 204) noted that the genera *Composita* and *Spirigerella* are very similar and fully discussed both genera drawing attention to internal differences between them. Three internal moulds of ventral valves (UWA 31572a, 31572b, 31572c) and one external mould of a ventral valve (UWA 31572d) from the High Cliff fauna are referred to *Composita.* By comparison with *Composita advena* Grant (1976) from the late Early Permian of Thailand, present material is more rounded in outline but possesses comparable ventral muscle scars that are rounded in juvenile specimens and more elongate in larger specimens (accentuated by thickening of the shell in the valve posterior). Despite the specimens being inadequate for detailed species comparison, the High Cliff record does provide another example of a generic link between the Early Permian faunas of Western Australia and Peninsular Thailand (see Archbold & Shi 1995 for additional discussion).

Order TEREBRATULIDA Waagen, 1883

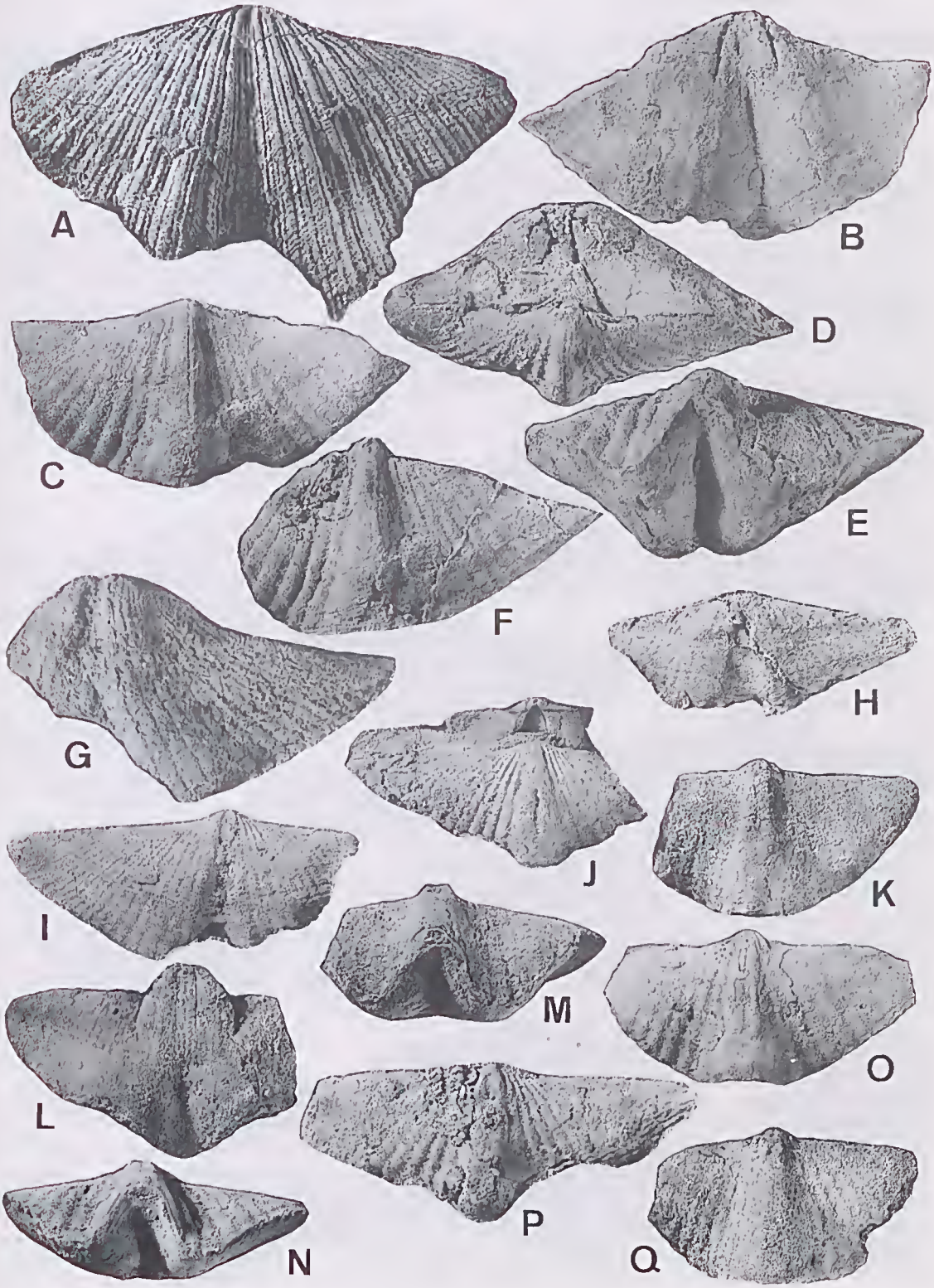
Suborder TEREBRATULIDINA Waagen, 1883

Superfamily DIELASMATOIDEA Schuchert, 1913

Family DIELASMATIDAE Schuchert, 1913

Subfamily DIELASMATINAE Schuchert, 1913

Fig. 14. A, *Neospirifer (Neospirifer)* sp., WAM 69.760, latex cast of ventral valve external mould, ×1. B–G, *?Cyrtella* sp. B–F, CPC 34599, internal mould of shell in ventral, dorsal, posterior and anterior views and latex cast of dorsal valve external mould, ×1. G, WAM 69.760a, latex cast of ventral valve external mould, ×1. H–Q, *Woolagia playfordi* gen. et sp. nov. H, UWA 33761, latex cast of ventral valve external mould, ×1. I, GSWA 49477, latex cast of ventral valve external mould, ×1. J, UWA 34286, latex cast of dorsal valve external mould, ×1. K–M, UWA 33762, internal mould of shell in dorsal, ventral and anterior views, ×1. N, O, UWA 34285a, internal mould of shell in anterior and dorsal views, ×1. P, GSWA 49476, latex cast of dorsal valve external mould, ×1. Q, GSWA 49478, internal mould of dorsal valve, ×1.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Genus Hoskingia Campbell, 1965

Type species. *Dielasma trigonopsis* Hosking, 1933a.

Hoskingia skwarkoi sp. nov.

Fig. 17A–L

'Dielasma' sp. nov. B Dickins 1957: 2.—Playford 1959: 19.
Hoskingia sp. nov. Archbold 1988: 47.—Archbold 1993a: 316.

Holotype. GSWA 49474, internal mould of complete shell.

Etymology. For Dr S. K. Skwarko, collector of the holotype and three paratypes of the species.

Paratypes. GSWA 49472,49473, two internal moulds of mature shells; GSWA 49475, anterior portion of external mould of ventral valve; UWA 33700, internal mould of complete juvenile shell.

Size ranges. Maximum width, 20–41.5 mm; length of ventral valve, 24–50.5 mm; length of dorsal valve, 22–46 mm; thickness, 10–18.5 mm; height of median fold, 0–4 mm.

Diagnosis. Large species with pronounced triangular posterior outline at maturity. Ventral internal median ridge distinct.

Description. Large species with ventral profile evenly convex, dorsal profile gently convex. Maximum width from 60 to 70% of shell length. Anterior outline rounded in juvenile specimens, tends to straight anterior margin at maturity. Lateral commissure weakly sinuate, anterior commissure sulciplicate at maturity. Ventral median fold distinct at maturity, feebly developed on juvenile specimens, slightly more than one-third valve width. Umbo sub-erect, foramen large (5.5 mm on holotype), mesothyrid.

Exterior with delicate growth lines, occasionally more prominent especially near anterior margin.

Pedicle collar strong, entire. Dental plates thin, widely spaced, short, located along outer shell wall. Muscle field elongate, suboval, slightly striate at maturity. Median ridge distinct, gently rounded crest.

Sockets distinct, crural bases distinct, thickened. Septalium sessile. Adductor scars elongate.

Comments. *Hoskingia skwarkoi* sp. nov. is a large species and is closest to *H. nobilis* (Etheridge, 1907a) from the Baigendzhinian Mingenew Formation of the Perth Basin (see Campbell 1965 and Archbold 1996 for recent descriptions of Etheridge's species). *H. nobilis* possesses a less triangular posterior outline, a lower ventral median ridge and a more rounded anterior outline at maturity than *H. skwarkoi*. Other Western Australian species of *Hoskingia* were well described by Campbell (1965).

Family GILLEDIIDAE Campbell, 1965

Subfamily GILLEDIINAE Campbell, 1965

Genus Gilledia Stehli, 1961

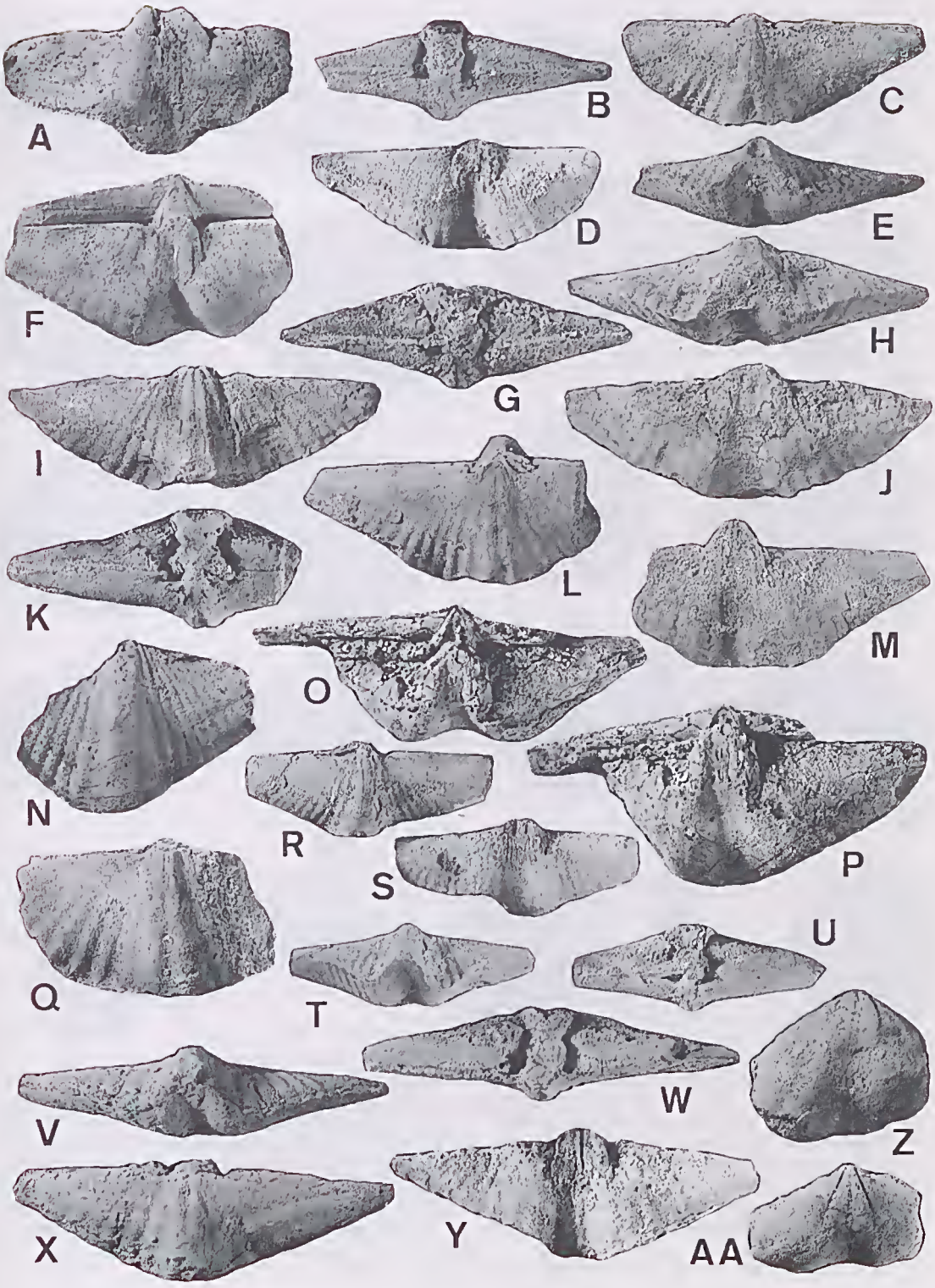
Type species. *Terebratula cymbaeformis* Morris, 1845.

Gilledia woolagensis Campbell, 1965

Fig. 17M–V

'Dielasma' sp. nov. A, Dickins 1957: 2.—Playford 1959: 19.
Gilledia woolagensis Campbell 1965: 82, pl. 9, figs 42–47.—Playford et al. 1976: 100.—Archbold 1988: 47.—Archbold 1993: pl. 45, figs 21, 24, 25, microfiche 5: 123.—Skwarko 1993: 92.—Archbold 1993a: 316.

Fig. 15. A–Y, *Woolagia playfordi* gen. et sp. nov. A, UWA 31795, internal mould of ventral valve, ×1. B–E, UWA 33688, internal mould of shell in posterior, dorsal, ventral and anterior views, ×1. F, GSWA 49479, internal mould of ventral valve, ×1. G–J, UWA 34285c, holotype, internal mould of shell in posterior, anterior, dorsal and ventral views, ×1. K–M, UWA 33760, internal mould of shell in posterior, dorsal and ventral views, ×1. N, GSWA 49478 counterpart, external mould of dorsal valve, ×1. O, P, UWA 38552, internal mould of ventral valve in posterior and ventral views, ×1. Q, UWA 33760, internal mould of dorsal valve, ×1. R–U, UWA 34386, internal mould of juvenile shell in dorsal, ventral, anterior and posterior views, ×1. V–Y, UWA 34285h, internal mould of shell in anterior, posterior, dorsal and ventral views, ×1. Z, AA, *Tomiopsis rarus* Archbold & Thomas, 1986, UWA 32552, internal mould of ventral valve, ×1.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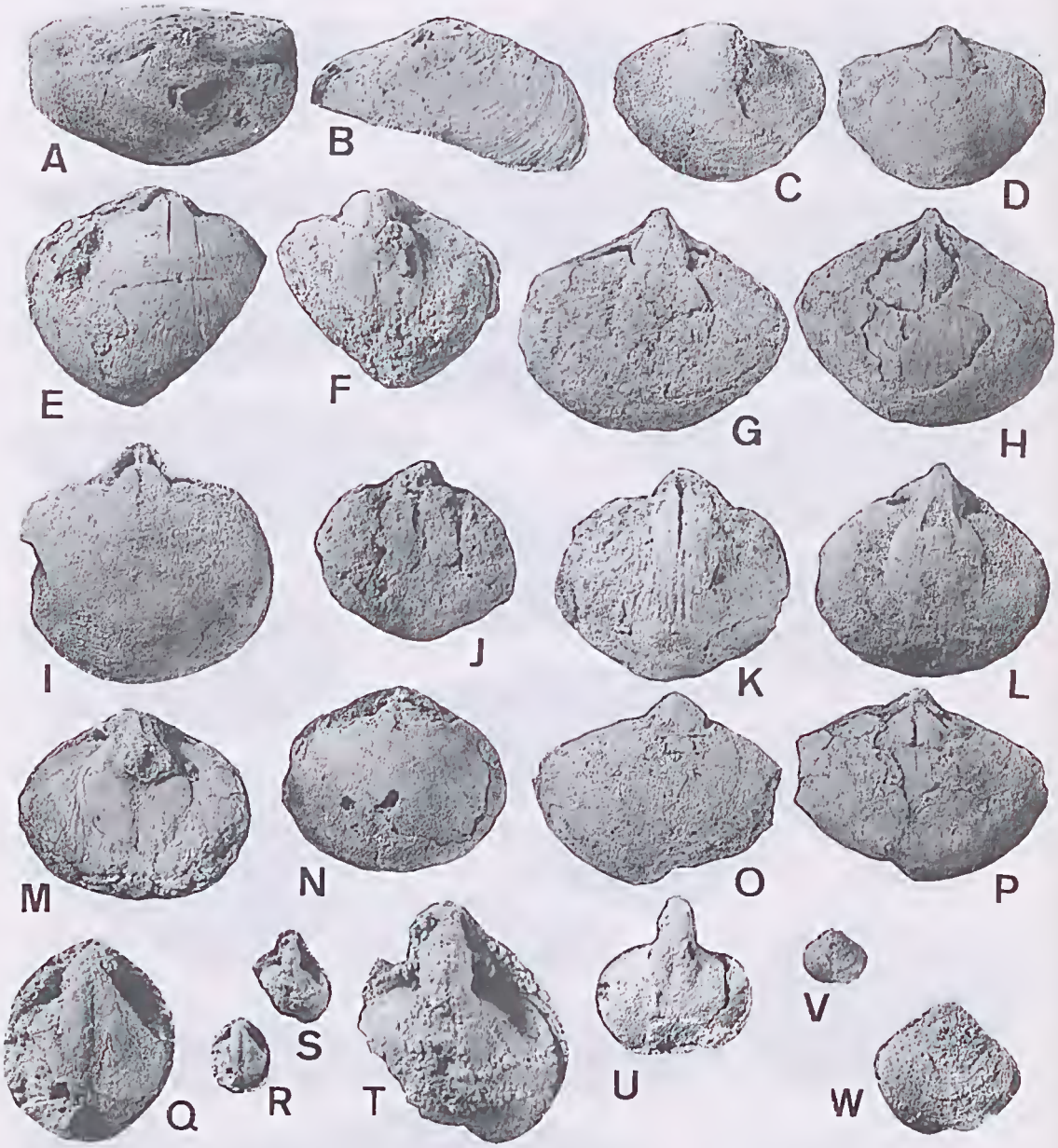

Fig. 16. A–P, *Cleiothyridina perthensis* sp. nov. A, B, GSWA 49480 latex cast of mould of posterior shell in posterior and ventral views, ×1. C, D, UWA 33366, internal mould of shell in ventral and dorsal views, ×1. E, F, GSWA 49481, internal mould of shell in dorsal and ventral views, ×1. G, H, UWA 32753, internal mould of shell in ventral and dorsal views, ×1. I, UWA 33761, internal mould of dorsal valve, ×1. J, K, UWA 32755, internal mould of shell in ventral and dorsal views, ×1 and ×1.2. L, UWA 38552a, internal mould of shell in ventral view, ×1.2. M, N, holotype, UWA 31563, internal mould of shell in ventral and dorsal views, ×1.2. O, P, UWA 31554, internal mould of shell in ventral and dorsal views, ×1. Q–W, *Composita* sp. Q, R, UWA 31572a, internal mould of ventral valve, ×3.5 and ×1. S, T, UWA 31572b, internal mould of ventral of valve, ×1 and ×4. U, UWA 31572e, internal mould of ventral valve, ×2.5. V, W, UWA 31572d, latex cast of external mould of ventral valve, ×1 and ×3.

Comments. This species was well described by Campbell (1965) on the basis of some 18 specimens, and 2 specimens were illustrated by him. Additional material (UWA 31563i–31563l, UWA 31564k) is illustrated herein in order to demonstrate the greater variability of the species with regard to shell outline and profile than indicated by Campbell's illustrations of the species.

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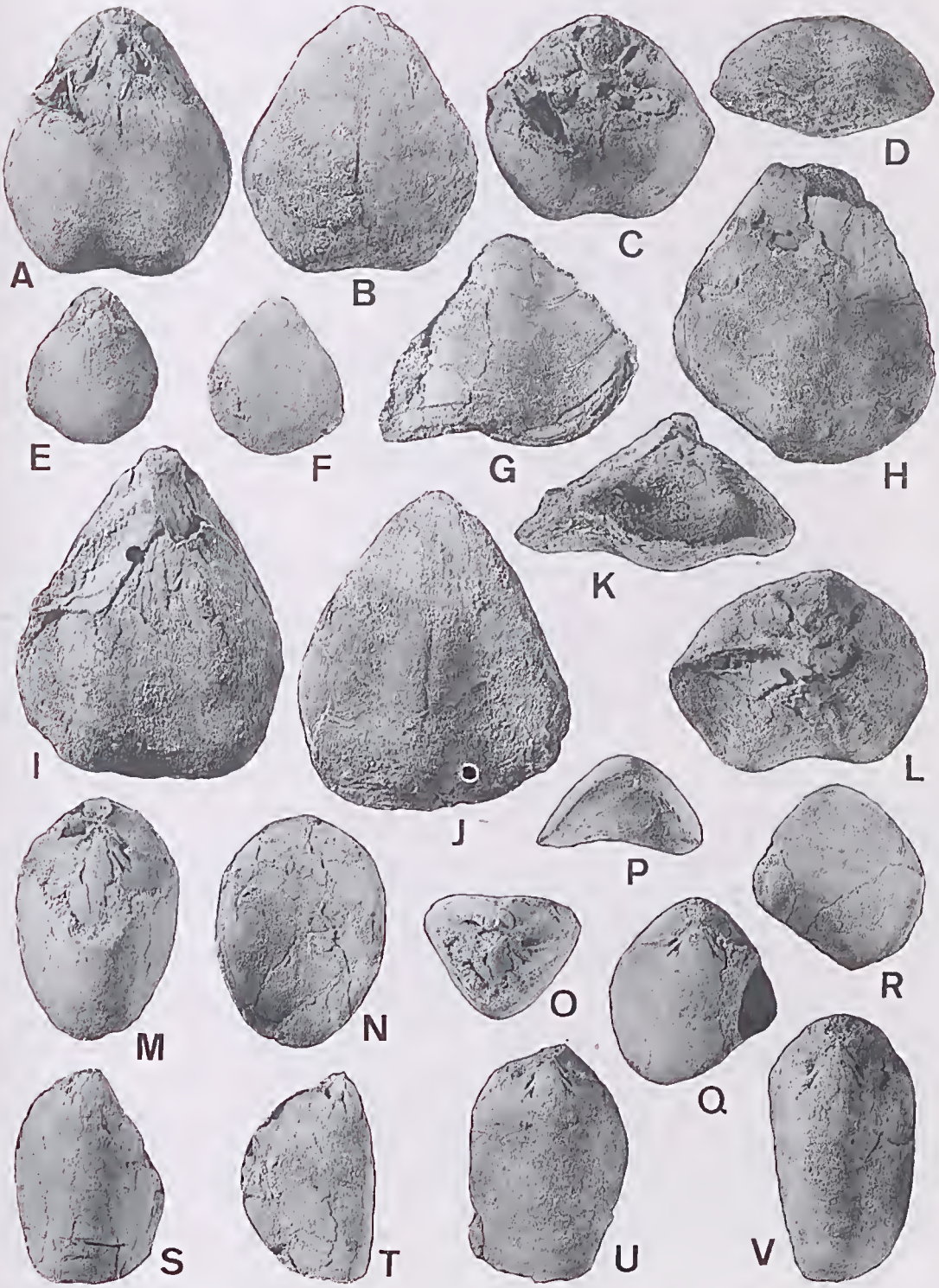
Fig. 17. A–L, *Hoskingia skwarkoi* sp. nov. A–D, GSWA 49472, internal mould of shell in dorsal, ventral, posterior and anterior views, ×1. E, F, UWA 33700, internal mould of juvenile shell in dorsal and ventral views, ×1. G, GSWA 49475, latex east of external mould of anterior of ventral valve, ×1. H, GSWA 49473, internal mould of shell in dorsal view, ×1. I–L, GSWA 49474, holotype, internal mould of shell in dorsal, ventral, anterior and posterior views, ×1. M–V, *Gilledia woolagensis* Campbell, 1965. M–P, UWA 31563i, internal mould of shell in dorsal, ventral, posterior and anterior views, ×1. Q, R, UWA 31563j, internal mould of shell in dorsal and ventral views, ×1. S, T, UWA 31564k, internal mould of shell in dorsal and profile views, ×1. U, UWA 31563k, internal mould of shell in dorsal view, ×1.5. V, UWA 31563l, internal mould of shell in dorsal view, ×1.5.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